

Spring 5-4-2018

Architecture of Adaptation: Structure in Nature

Salman Sajwani

Follow this and additional works at: https://digitalcommons.kennesaw.edu/barch_etd



Part of the [Other Architecture Commons](#)

Recommended Citation

Sajwani, Salman, "Architecture of Adaptation: Structure in Nature" (2018). *Bachelor of Architecture Theses - 5th Year*. 79.
https://digitalcommons.kennesaw.edu/barch_etd/79

This Thesis is brought to you for free and open access by the Department of Architecture at DigitalCommons@Kennesaw State University. It has been accepted for inclusion in Bachelor of Architecture Theses - 5th Year by an authorized administrator of DigitalCommons@Kennesaw State University. For more information, please contact digitalcommons@kennesaw.edu.

ARCHITECTURE OF ADAPTATION

STRUCTURE IN NATURE

Request for Approval of Thesis Research

Project Book Presented to:
M. Saleh Uddin, Ph.D.

and to the

Faculty of the Department of Architecture
College of Architecture and Construction Management

by

Salman Sajwani

In partial fulfillment of the requirements for the Degree

Bachelor of Architecture

Kennesaw State University
Marietta, Georgia

Spring 2018

Thesis Collaborative 2017-2018
Request for Approval

Department of Architecture
College of Architecture and Construction Management
Kennesaw State Univesity

Full Name: Alisalman T Sajwani

Thesis Title: Architecture of Adaptation: Structure in Nature

Thesis Summary : The objective of this thesis is to design a pavilion that can adapt to its surroundings by responding to the environment as well as the users. This pavilion is inspired by the geometry of nature. Nature is constantly adapting to the it’s surroundings but does not merely create a new form without a desired function. This method is accomplished by a system known as fractals, a principle that nature uses in coherence with modular systems that divide and subdivide to create structure. This thesis will focus on the complex fractal shapes of trees, to understand the physical, biological and mechanical function of these tall giants that have withstood the test of time. Parez Garcia refers to five natural arrangements in his paper Natural Structures: Strategies for geometric and morphological optimization.

Student Signature : _____Date_____

Approved by:

Thesis Advisor : _____Date_____

Dr. M. Saleh Uddin

Thesis Coordinator: _____Date_____

Professor Elizabeth Martin-Malikian

Dedication

Gratitude from the Author

Acknowledgment

My thesis could not have been possible without the guidance and Support of my thesis professors: Dr. Saleh Uddin and Proffesor Zamila Karimi.

The challenge they posed to me to keep pushing my thesis further and ask questions helped me seek plausible solutions that have molded my thesis into what it is.

TABLE OF CONTENTS

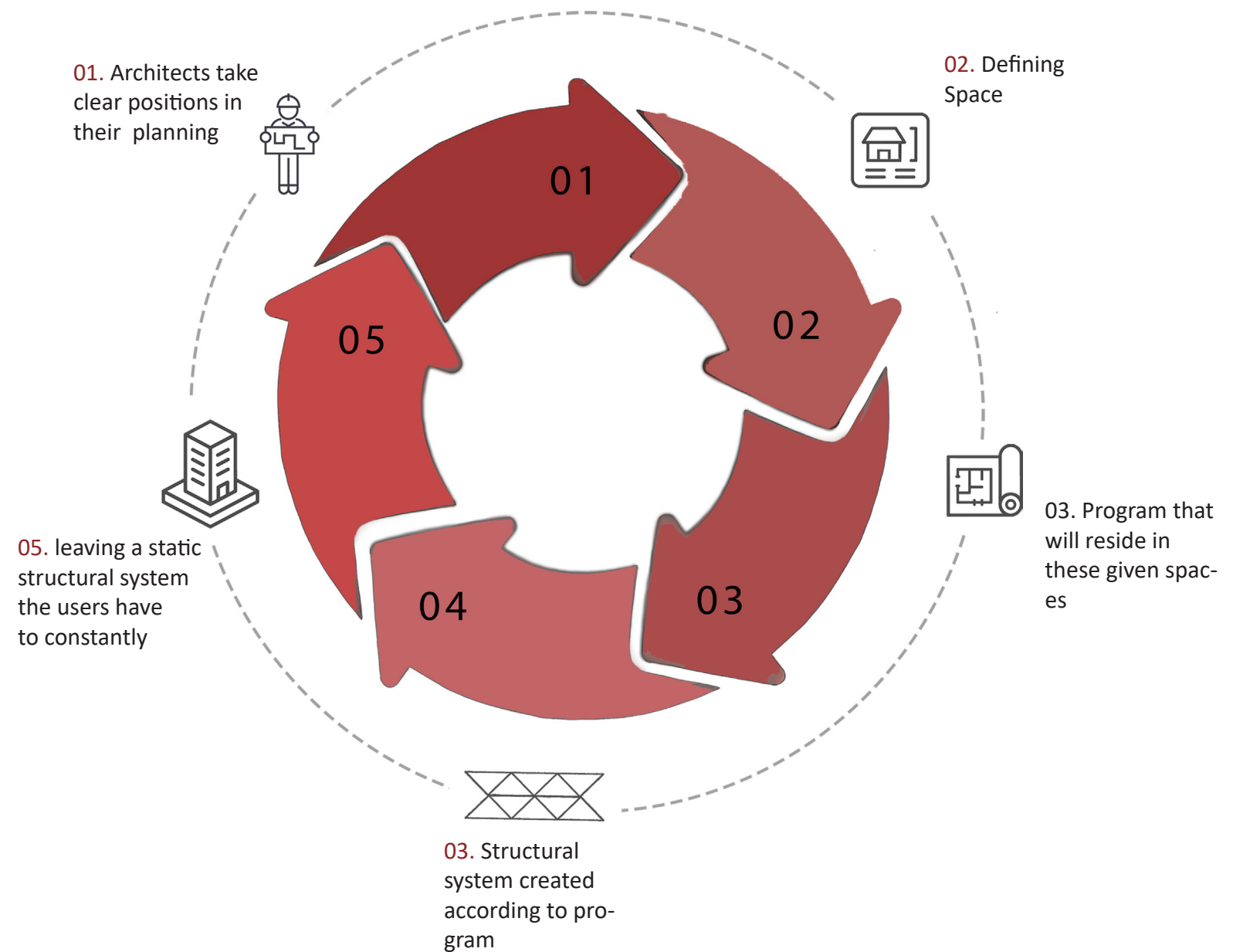
CHAPTER 1.0 -Design Theorem	
1.1. Design Hypothesis.....	08
1.2. Relevance of the Design Hypothesis.....	10
1.2.1Natures Relevance in Design.....	12
1.2.2 Pneumatical Growth.....	06
1.2.3 Understanding Fractals.....	18
1.2.4 The Fractal Branching of Trees.....	20
1.2.5 INSPIRED BY NATURE.....	22
1.3.0 PROPOSED PROJECT.....	26
1.3.1 CASE STUDIES.....	28
 CHAPTER 2.0_DESIGN CONTEXT	
2.1.1 SITE SELECTION AND SIGNIFICANCE.....	31
2.1.2EXSISTING SITE CONDITIONS.....	33
2.1.3 SITE ANALYSIS.....	34
 CHAPTER 3.0_DESIGN PROCESS	
3.1.1 DECODING FRACTAL BRANCHING.....	38
3.1.2 DECODING SPIRAL FRACTALS.....	42
3.2.0 TECHNIQUE AND TECTONICS.....	47
 CHAPTER 4.0_DESIGN INTEGRATION	
	50
 CHAPTER 5.0_FINAL BOARDS.....	
	56
 BIBLIOGRAPHY.....	
	58

1.1 | DESIGN HYPOTHESIS

Introduction

The concept of a piece of architecture taking on adaptive qualities is based on the ability that a system can effectively respond to the environment and the evolving programs. Architects strive to create designs that respond to external changes, creating a challenge with kinetic and the immovable aspects of a building, which can be identified as the systems of walls, ceilings, and columns. This system however, creates the foundation of a successful built environment but also hinders the adaptive and flexible qualities. These systems are implemented permanently and confined to the site and program that has been defined to them. Keeping this challenge in mind, one cannot help to see nature and be inspired by the adaptive and the systematic qualities that nature constantly is using, from the fractal branching of a tree to the efficient way of filling space in a honeycomb. We can start seeing a trend in nature and the adaptive qualities it tends to. Nature does not create form without a function.

This thesis investigates the discourse that architects have had with the adaptive qualities of architecture by taking inspiration from nature as a design strategy. The project instantiates this notion into a pavilion that is programed for informal performance and exhibition space. This pavilion will test out the performative qualities by responding to the exterior environment and the evolving nature of the program, concluding with a system that will bring forth a refined appearance all in one single configuration.



1.2 | RELEVANCE OF THE DESIGN HYPOTHESIS

Adaptive Architecture

Our lives are in a continuous motion with the natural world in which we reside, yet the spaces we inhabit are static. The term adaptation is commonly referred to as the morphology and evolution of architecture through the notion of how a building is conceived and built along with the technological advancements that given period of time has access to. Architecture currently uses adaptation in a way that occurs through the generations, with constant improvements, evaluation, and feedback.

“Adaptation is the evolutionary process whereby a population becomes better suited to its habitat. This process takes place over many generations, and is one of the basic phenomena of biology.”

– On the Origin of Species, Charles Darwin

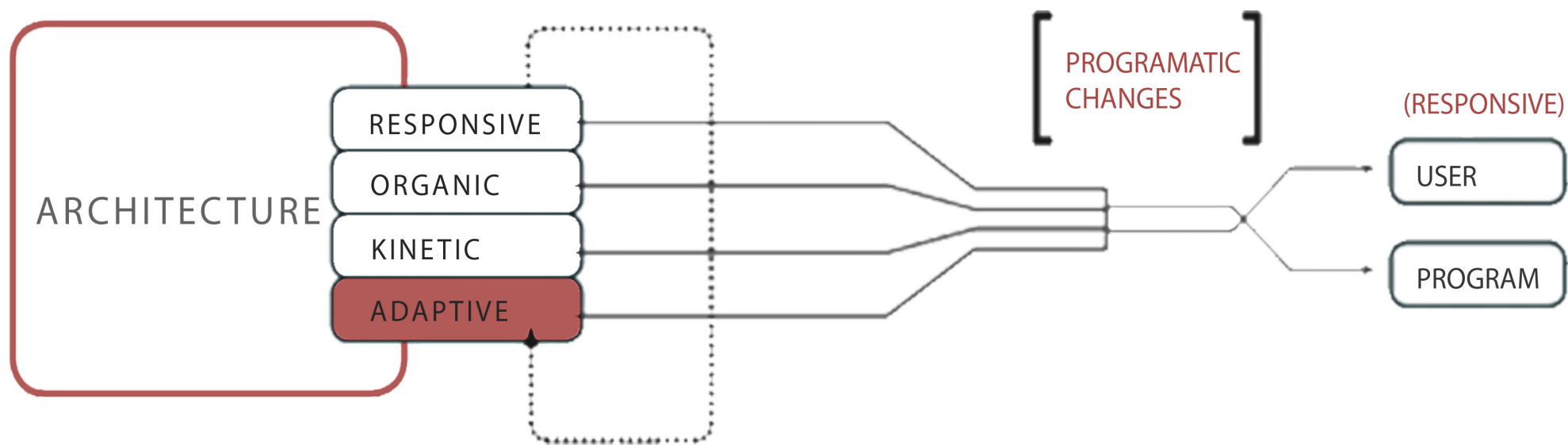
In his publication of Architectural Robotics, Green underlines the resilient nature of architecture to have adaptive traits due to a series of combination of the functional, economic, legal and

frequently political demands imposed on architecture works (Green 26). These variables have closed the minds of many architects as well as clients, leaving a gap in the architectural discourse of having “functional play” Architectural work has lent itself to becoming a system that is more typological rather than having the multi-functional qualities this thesis is striving to achieve. Green brings attention to the wastefulness of resources when it comes to a building that only serves one function and neglects the human population that is seeking shelter and places to meet, work and play. This resilient discipline of architecture is motivated by “the quest for a universal standard for measuring it: for designing its component parts and organizing these parts to constitute the larger work.” The neglect for architecture to adapt takes root in the era of the renaissance, when architecture was to encompass the concept that “nothing may be added, taken away or altered” (Alberti). He also emphasizes that beautiful architecture cannot be modified in that timeless “classical” architecture.

This thesis will explore the structural and performative qualities

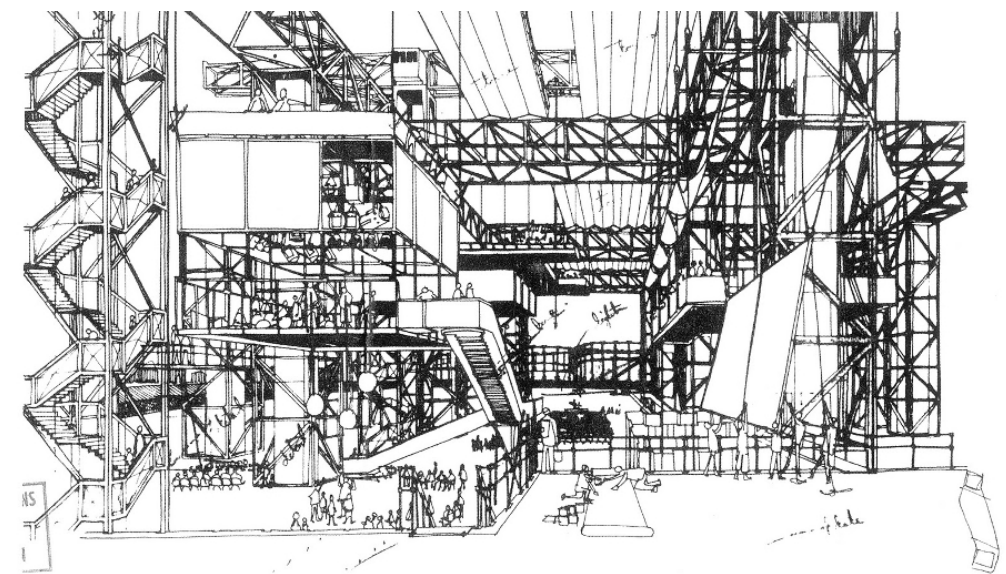
that can be altered and shape-shift spaces that can adapt to the environmental changes in the desired location where global climatic changes that occur can be input as data and the architecture itself adapts in a real-time performative creation. Architecture often uses this system in the creation of facades, where the system begins to have adaptive qualities to sunlight, but the essence is lost in the adaptive qualities that architecture is so desperately striving for.

“The fluctuating parameters and conditions of the cities and changing environments, architecture needs to serve to a multitude of functions through its life cycle. Thus it is necessary that architecture responds to all the fluctuating parameters and serves the purpose of its existence (Verma). This thesis takes on these parameters and takes the systems of a wall, ceiling column and defines them to be truly one cohesive piece of architecture. That is when the architecture goes merely from a shading device to a system that begins to adapt to take on the attributes of a dynamic system.



The will for architecture to be responsive can be seen in the 1936 prototype by Cedric Price in his Fun Palace. His proposal was defined by the temporary circulation and enclosure system where the interior walls were suspended from a space frame. This system radically transformed the experience of architecture letting program and circulation of a building become a dynamic aspect that was defined by the user. It was far ahead of its time. Price's Fun Palace had a strong influence on Renzo Piano and Richard Rogers where the high tech appeal of the Fun Palace was demonstrated in the Centre Georges Pompidou (1977). Both systems have common traits of separating the major parts of the building such as the structure, circulation, and skin. The intention of the separation of the three different components allowed the increase of flexibility and adaptation that could change over time. With this sort of system, unfortunately, the only aspect that stood out was the flexibility, dissolving the adaptive qualities. Price's influence in the responsive nature of the user acting on the building had some performative qualities, but a more contemporary style of adaptive qualities is better exemplified by Reyner Banham. He explained the responsiveness to the weather and environment and was the driver of his 1969 essay *A Home is Not A House*. In this theoretical essay, he iterates the dynamic modifications a campfire and a tent, revealing the thermal properties in response to the environment (Meagher). This theoretical paper explores the nature and desire for adaptation and the theoretical studies as well as a mobile house that is structured for rapid reconfiguration in response to the exterior or interior environments. Another way of categorizing the system of adaptivity is

through the rate of change Brand underlined in his 1995 book, *How Buildings Learn*. He lays out a building into layers of components that have a relative rate of change through the variation of time and states that all components of a building are constantly in a state of change (Brand). As can be seen in the studies by Price, Banham, and Brand the adaptive qualities and the theory behind having a building or sets of components have the flexibility and a responsive attitude that are crucial when looking at the future of architecture.



(Figure 1) Cedric Price, Fun Palace 1936 proposal

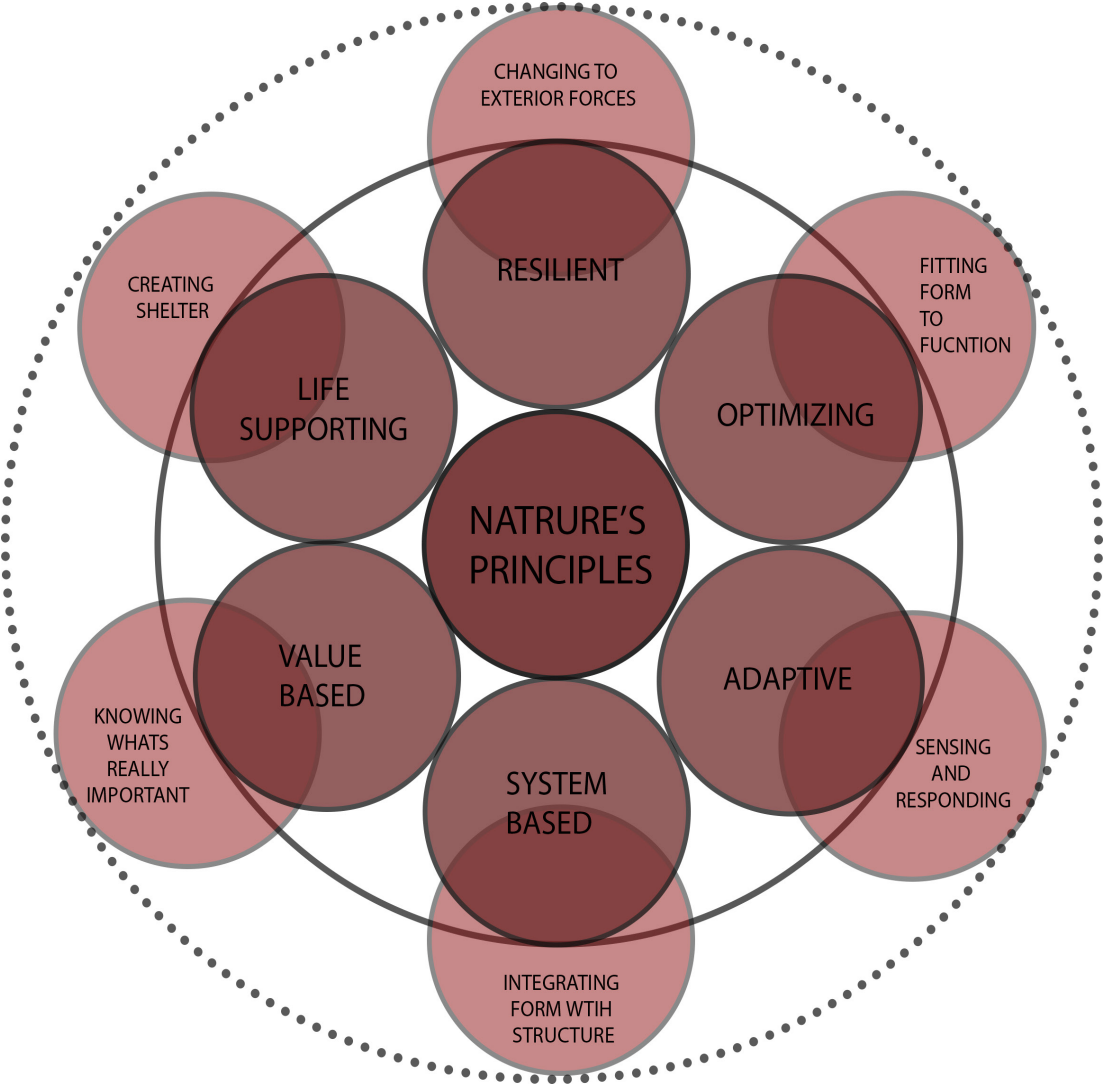
1.2.1 | RELEVANCE OF THE DESIGN HYPOTHESIS

Nature Adapts

The adaptive qualities that this thesis is striving to achieve is based off the search for a form that will allow the fusing of a wall, ceiling, and column to design a coherent structure that can adapt to the social and environmental aspects. One can only begin looking at the most efficient examples that can be found in nature.

The natural environment brings a sense of inspiration, through the beautiful and simultaneously functional attributes that nature provides is simply put, a design goal for architecture. Natural and fractal forms can assist with design decisions that can lead to an adaptable system in the end.

Nature uses its function to create a form, This underlying process will help in order to understand how our built environments can follow the same principles and use the adaptive qualities of nature. It will be laid out through the rest of this section to better understand the design influence that nature offers design decisions and concluding with an adaptable system.



1.2.1 | RELEVANCE OF THE DESIGN HYPOTHESIS

Natures Influence

“Biomimetic” nature is the source of inspiration to create “artificial systems that copy function from natural ones (Vincent). This theory has always inspired different fields of knowledge from the arts, philosophy, technology, physics, politics, medicine and of course architecture, but when it comes to the structural properties of architecture this system was not explored until the 20th century when it led to the inspiration of lightweight structures (Garcia). In (Figure 2), the general use of construction methods was applied without the intervention and analysis of the natural.

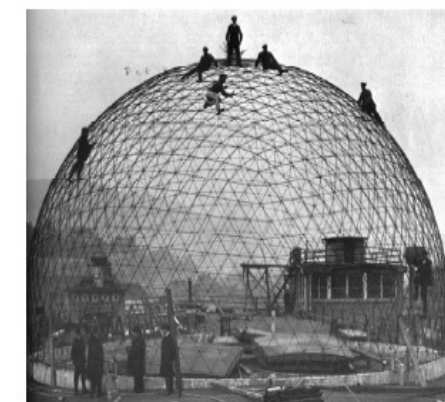
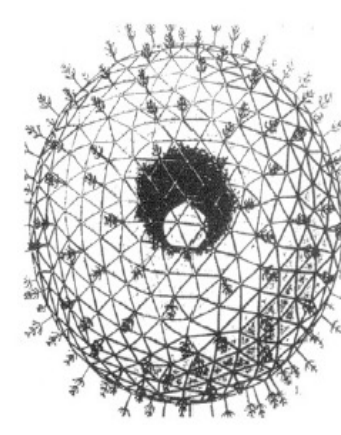
A| Beam-and-column system:
Bending, some flexibility.

B| Lightened skeletons:
Division of compression and tension, flexibility.

C| Active-form surfaces:
Load-bearing by morphology, curvature, folding.

D| Massive (masonry: walls, arches, vaults, domes):
Compression, stability, weight, rigidity.

The formation of studies done by Ernst Haeckel in his book Art Forms of Nature looks at microorganisms through an artistic and aesthetic analysis. During the same period, the book On Growth and Form was published, by biologist D'Arcy Thompson. He explained that “animal forms as funiculars of forces” both brought out the possibilities of new forms and structural systems that were directly influenced by nature. Lending to “optimal morphology extreme lightening, functional integration, and efficiency” in structure (Garcia). In (Figure 2) radiolarians studied by Haeckel influence the structural systems of the Planetarium in Jena.



Pictures of radiolarians (E. Haeckel) and Planetarium in Jena (C. Zeiss)

1.2.1 | RELEVANCE OF THE DESIGN HYPOTHESIS

NATURE DOES NOT CREATE


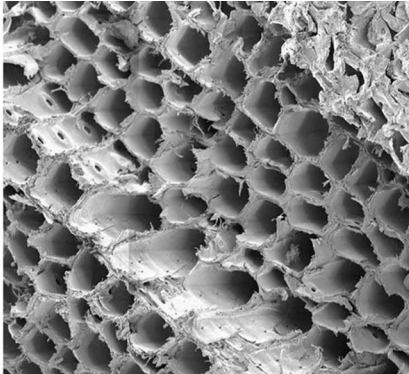
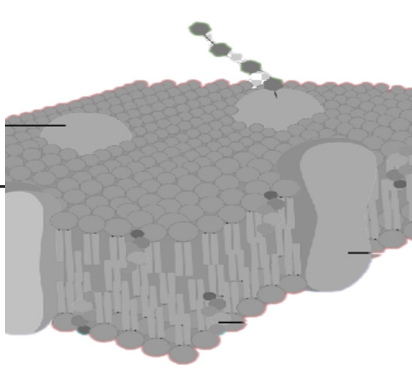
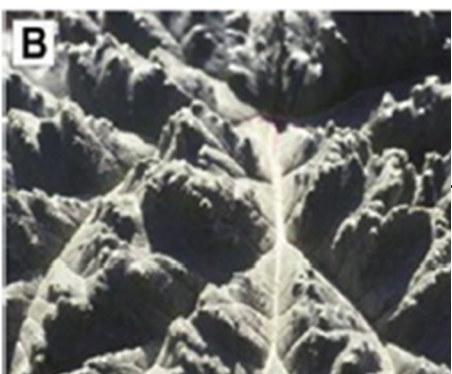
ORGANISM	TERMITE MOUND	TREE	CELL MEMBRANE	DESSERT RHUBARB
EXAMPLE	<p>Termite mounds are constructed of an extensive network of tunnels. The tunnels structure is considered to be an analogue of a lung, responsible for the global function of colony gas exchange. The regulation of gas is a complicated process that is related partially to ventilation inside the mound tunnels. In the egress tunnels air movement driven by wind</p>	<p>At the macroscopic level, wood is composed of parallel hollow tubes formed by the wood cells shape. These tubes are responsible for leading water and nutrients from the ground toward the tree's organs due to capillary forces opposing gravity</p>	<p>The membrane of a cell is constructed of two layers of lipid cells. Between these two layers there are channels of proteins which allow a passive movement (diffusion) of ions (ion channels), water (aquaporins) or other solutes through the membrane down their electrochemical gradient</p>	<p>The desert rhubarb has large leaves with a ridged structure that creates a surface of channels. These channels lead the rain toward the ground near the plant's root by the gravitation gradient</p>
FUNCTION	REGULATES THE GAS EXCHANGE	WATER AND NUTRIENTS	REGULATES IONS AND WATER	CHANNELS WATER
IMAGE				

TABLE 1: Solga, A., Cerman, Z., Striffler, B. F., Spaeth, M., and Barthlott, W., 2007, "The Dream of Staying Clean: Lotus and Biomimetic Surfaces," Bioinspiration

FORM WITHOUT A FUNCTION

SHARKS

The basking shark swims with open mouth in order to catch his food. His stretched jaw demonstrates an asymmetric structure as the inner part of the jaw is straight and the outer part of the jaw is curved. This asymmetric structure creates a passive flow of water through the shark's gills due to the pressure gradient between the bottom and the upper parts of the jaw. Thus, excess water is moved without investing precious energy or structural complexity compared to a solution

PINE

Pine scales are combined of two tissues. The inner tissue has a significantly lower coefficient of hygroscopic expansion fibbers than the outer tissue. As a result the scales are closed when it is humid and opened when it is dry

PUFFER FISH

Puffer fish (Tetraodontidae family) is able to inflate its body by swallowing water. The increased size of the inflated body makes it more difficult to be swallowed by predators. Thus the body volume is changed on time

SHELL

The membrane of a cell is constructed of two layers of lipid cells. Between these two layers there are channels of proteins which allow a passive movement (diffusion) of ions (ion channels), water (aquaporins) or other solutes through the membrane down their electrochemical gradient

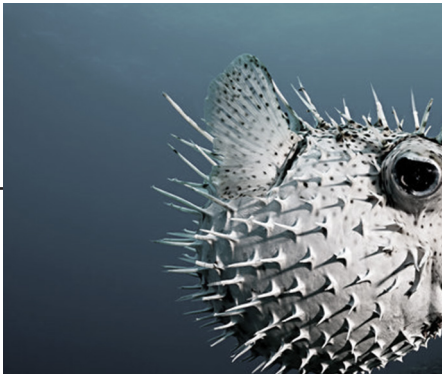
MOVE UPWATER



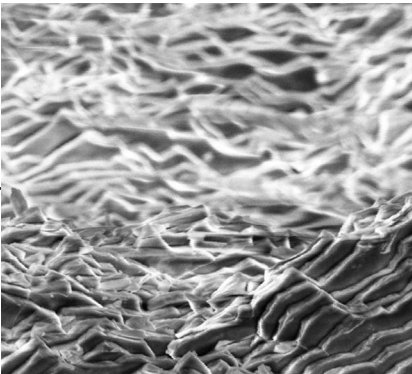
SCALES OPEN AND CLOSE



VOLUME OF BODY CHANGE

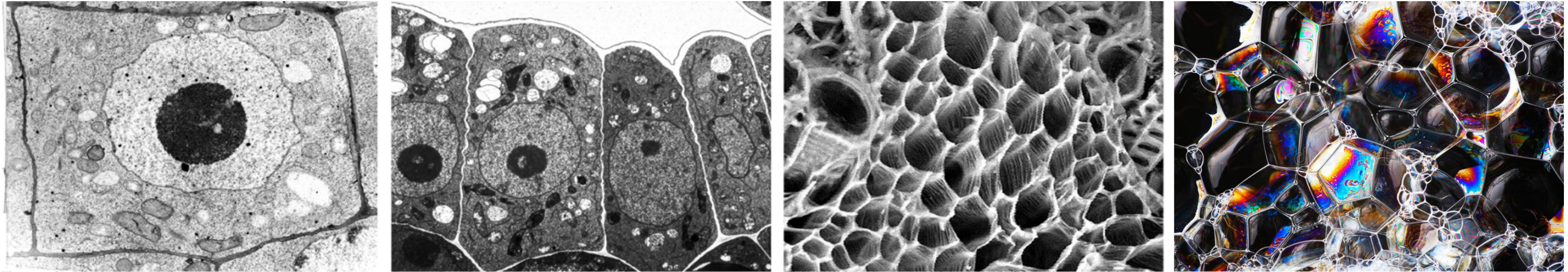


ABSORBS PRESSURE



1.2.2 | RELEVANCE OF THE DESIGN HYPOTHESIS

Perez Garcia refers to five natural arrangements in his paper Natural Structures: Strategies for geometric and morphological optimization. These include pneus, shells, trees, webs and skeletons all of which take on the four main factors, “nature of forces, global form, local design and quality of materials.” The two systems that this thesis will focus on, will investigate the Pneumatical Growth and the Fractal nature of trees.



(Figure 3)

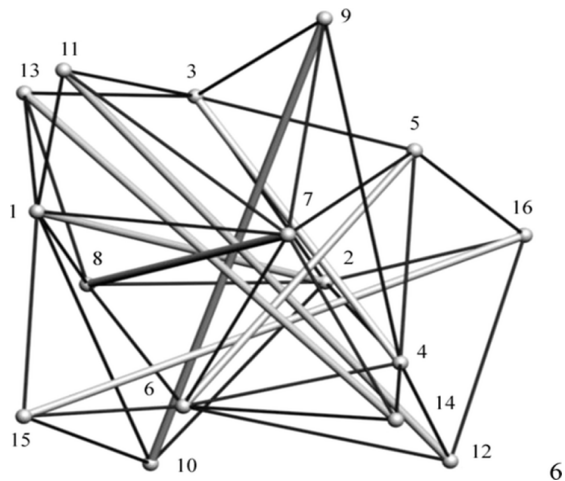
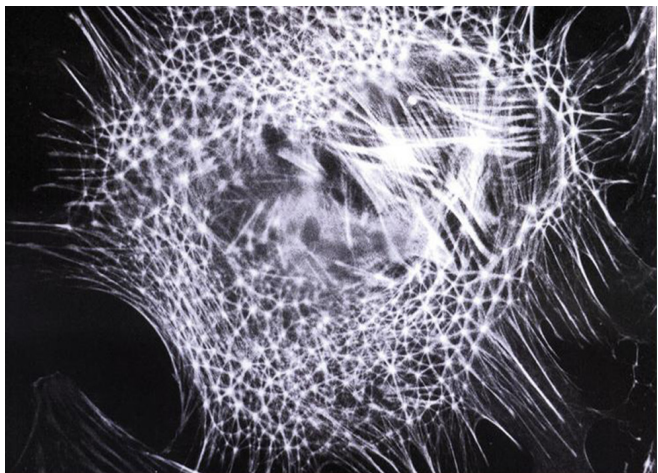
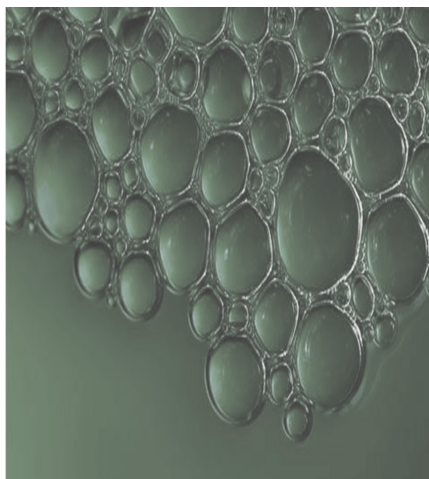
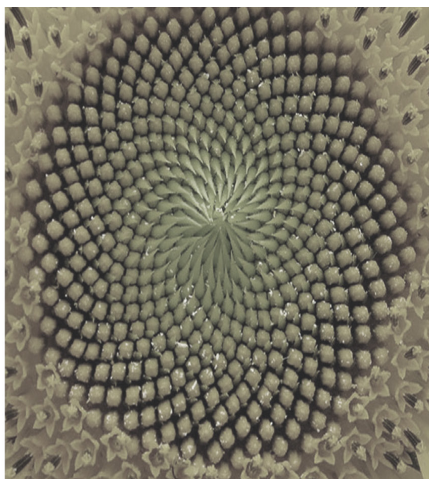
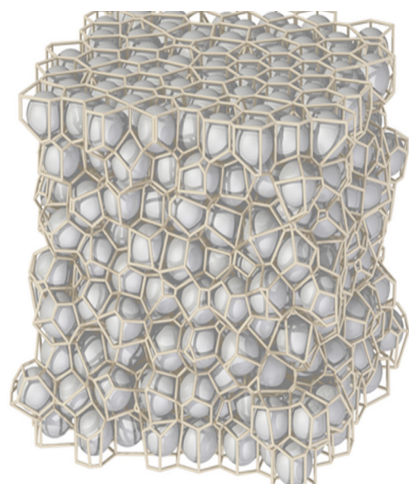
Pneumatical Growth

The pneumatic structures are the most efficient ones in terms of span and weight. A pneu

“consists of a ductile tensed envelope, internally pressurized by a fluid and surrounded by a medium” (Otto). So they are self-stabilized element, and because of this dependency of

the internal pressure made by a fluid, the result is a very adaptable structure which can easily change its form to accommodate to the surrounding geometry. larger scale, the formation of beehives is a translated example of the different orders of ‘pneu’.

1.2.2 | RELEVANCE OF THE DESIGN HYPOTHESIS



Combining Pneus

Pneu model of living objects is the way they combine themselves producing optimal grids with least-energy behavior. This is the principle of the “closest packing”: optimal ways of join solids in the plane or in the space, and is one of the most common geometric phenomena in Nature (Pearce) .

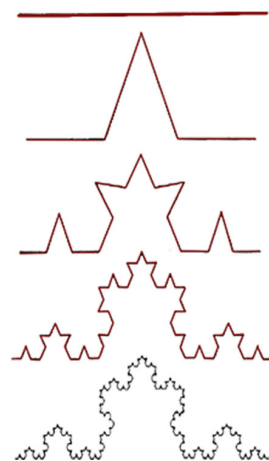
Transegrity in Pneus

In a closer approximation this system of exterior mobile envelope linked to an interior nucleus has been explained also as a tensegrity system (self-assembly structure composed of compression and tension elements in which load-bearing capacity comes from pre-stressing of the ensemble). Thus, cytoskeleton of cells is a framework of interconnected microtubules (compression) and filaments (tension). The efficiency of the arrangement lies in the possibility of changing its shape easily and adapting to the exterior surfaces and constrains.(PEARCE)

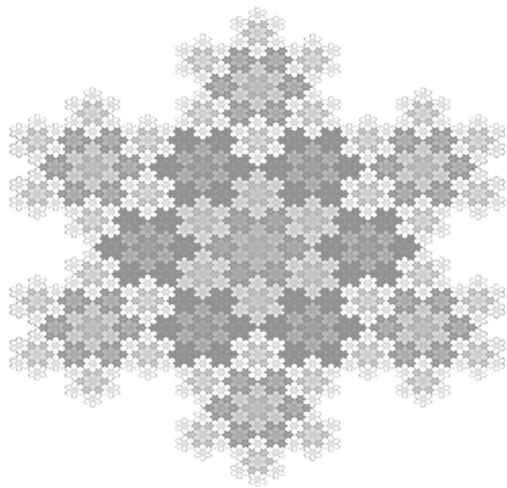
1.2.3 | RELEVANCE OF THE DESIGN HYPOTHESIS

UNDERSTANDING FRACTALS

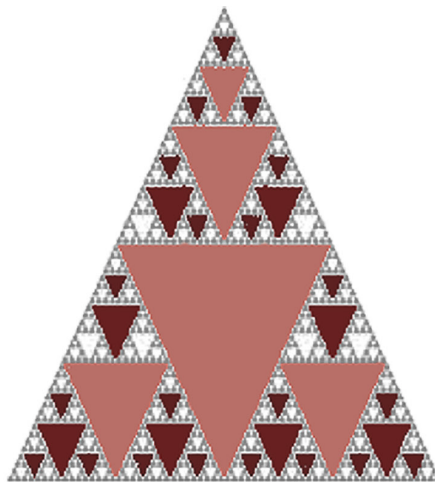
The importance of a fractal system is crucial when applying to the general outcome of this design. The fractal system is defined in the 1970's stating that it is a system that concludes in the abstract configurations of self-similar patterns and a recursive growth (Maderbolt). Looking at this system through a mathematical point of view can allow for a system to decrease and increase in scale. The figure below shows a recursive algorithm applied to a simple cube formation that represents the fractal system in a three-dimensional form. At each stage from 1-5, the model increased the amount of surface but kept the initial volume. This system was represented as a decreasing pattern with the possibilities of having an infinite amount of cubes but not increasing the volume content of the original cube.



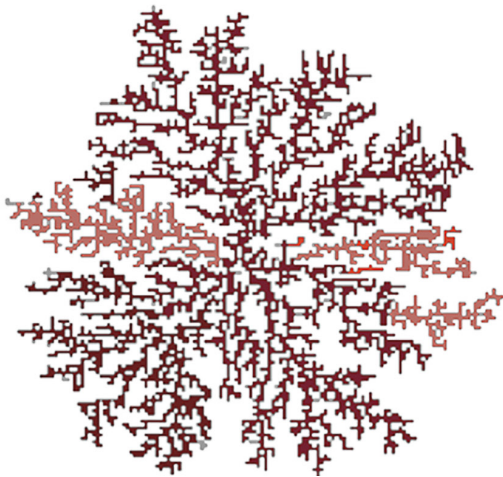
Koch curve, Bovill, Carl (1996). Fractal geometry in architecture and design. Boston: Birkhäuser



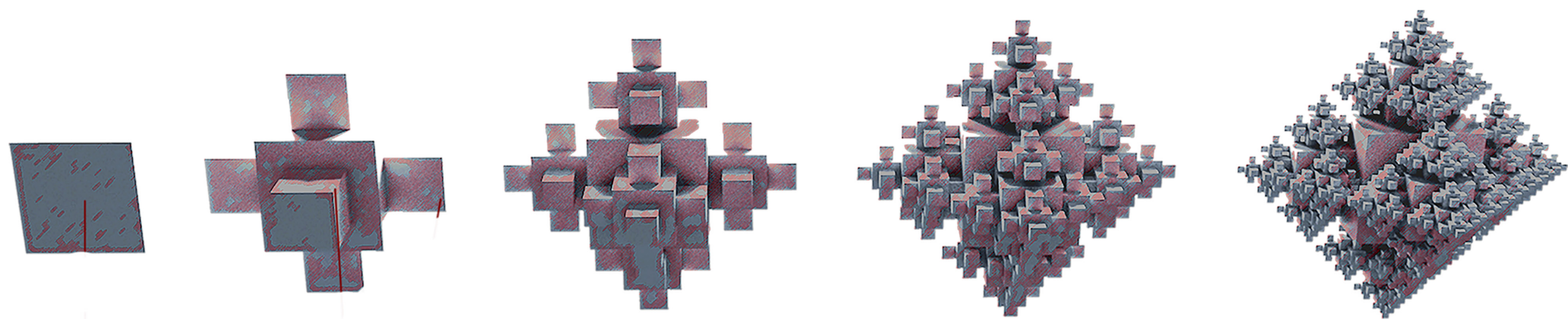
Koch Snowflake Arrays



Sierpinski Triangle, Sierpinski, Sieve (1915). Italian Art from the 13th century(Wolfram)



'Fractal generated by DLA using diffusion equation instead of random walk. ' from publication 'Quantum Diffusion-Limited Aggregation'



01
3D representation of fractal growth
based of off Sierpinski's Carpet

02

03

04

05

1.2.4 | RELEVANCE OF THE DESIGN HYPOTHESIS

Branching Fractals

Fractals are in many scenarios are not dependent on geometric patterns, they also refer to the process by which time and evolution have a direct impact when referring to the natural occurrence of fractals in nature.

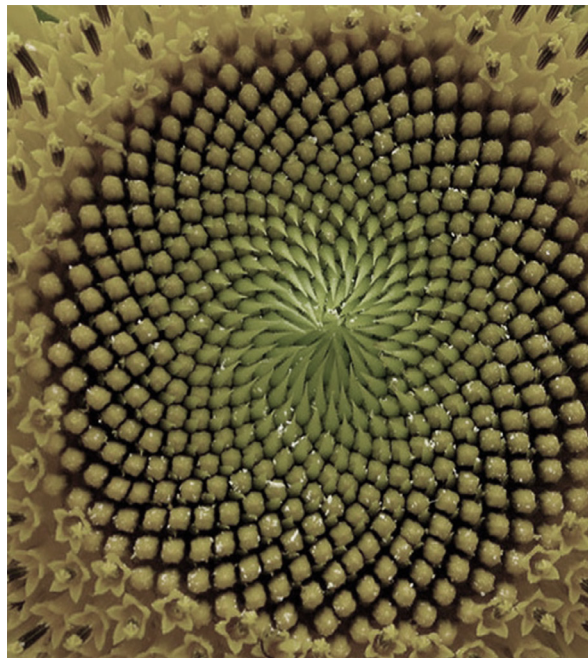
For many centuries, nature’s forms in many cases present fractal geometry in the structural sense, such as trees, shells, vegetables,etc these systems

can be seen in the use of light weighted structures such as arcs, tents, grid shell, bridges to name a few.

Fractals can be conceived by the method in to-day digital world by the use of 3d modeling and through the process of a generative approach based on mathematical composition (Huylebrouck)



Spirals Mathematically can be defined as the Fibonacci sequence (Golden Ratio) the proportions gradually increase and decrease creating forms this characteristic is identical to the concept of fractals as seen in the previous section, where this system differs is, the patterns in a spiral fractal can be predicted but also take on the qualities of a Pnues system (Closest packing) as seen in section 1.2.2



"Fractal mathematics use a complex algorithm to measure natural behaviors, forms and patterns throughout the universe this means the visual aspects of a fractal image aren't copying nature to create composition, they are nature."(Pauli Scott: Fractal Natures Equations)

1.2.5 | RELEVANCE OF THE DESIGN HYPOTHESIS

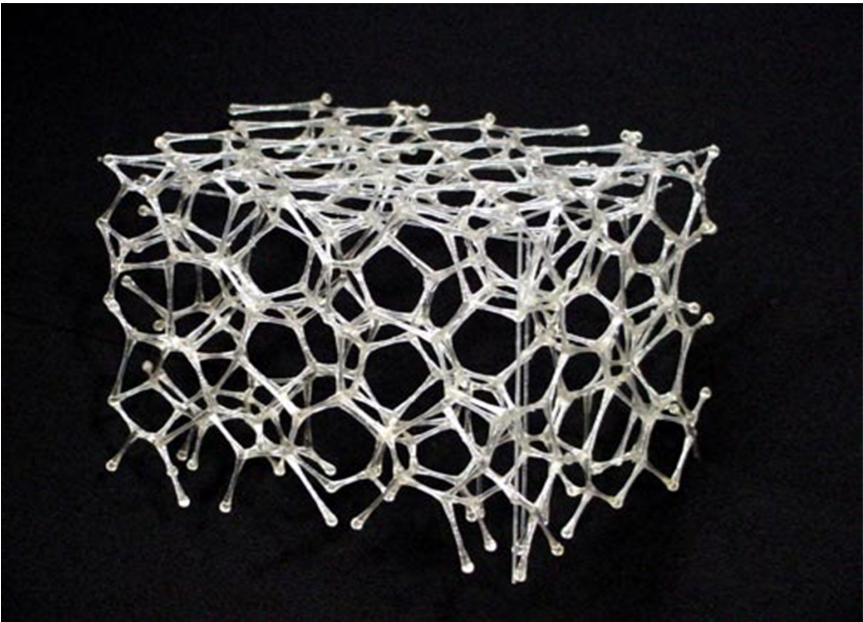
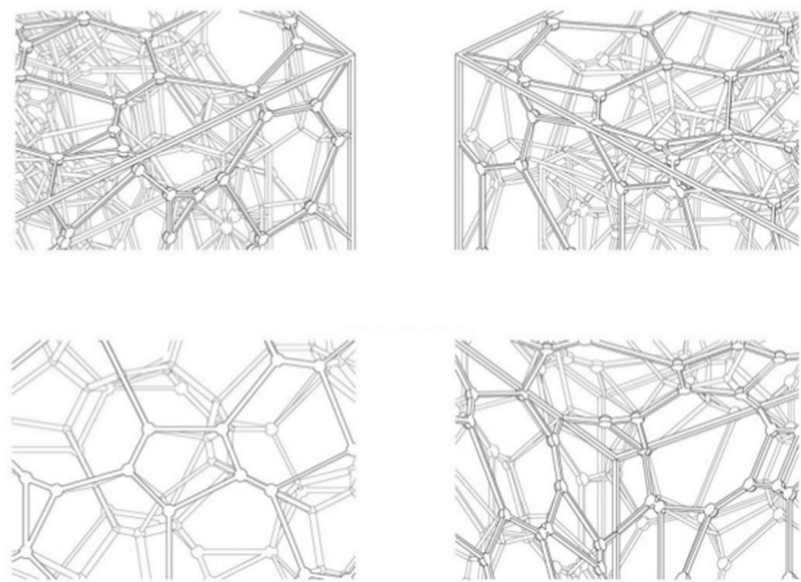
INSPIRED BY NATURE PNUES

THE WATER CUBE

Beijing, China

The concept of this Olympic building was derived from the characteristic by the uniform crystalline packing borrowed from mathematics. Soap-film bubbles were the initial starting points of inspiration. Lord kelvins question posed in 1887

“What space-filling arrangement of similar cells of similar volume, has minimal surface are?”
The system was created by repeating units of eight irregular polyhedral, six fourteen –faced and two twelve faced the sectional cut of the polyhedral created the randomization, no repeating, organic pattern.



Pnue Haus
Compound Camera

The compound camera is a 20ft inflatable installation composed of 109 pinholes camera . “ The structures flexible fabric allows people to push and distort the projected images, playing with the fundamental properties of light, optics, and vision in a tangible way” (Pneuhaus). The Installation directly correlates with the idea of closest packing of a pnue system. Creating a inflatable system that mimics the hexagonal grid to create a structure that involve the occupant to have an interactive experience with their built environment.



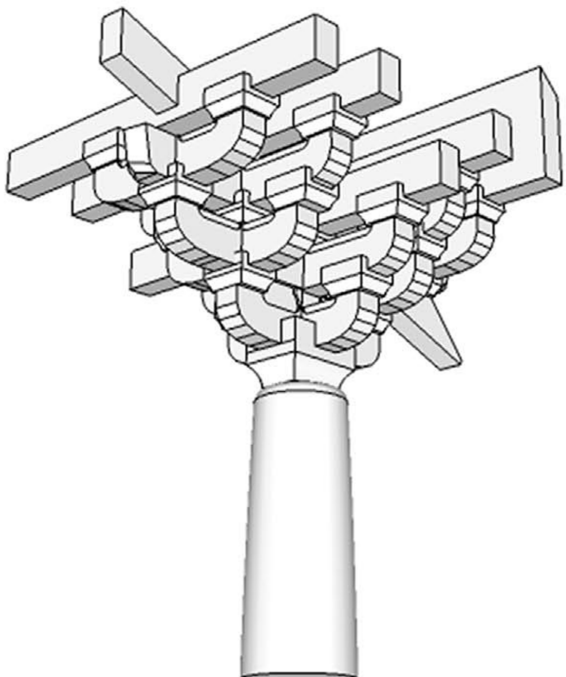
1.2.5 | INSPIRED BY NATURE BRANCHING OF TREES



Ancient Egyptian columns inspired by a bundle of papyrus plants in Luxor Temples, Egypt, built in 1400 BC



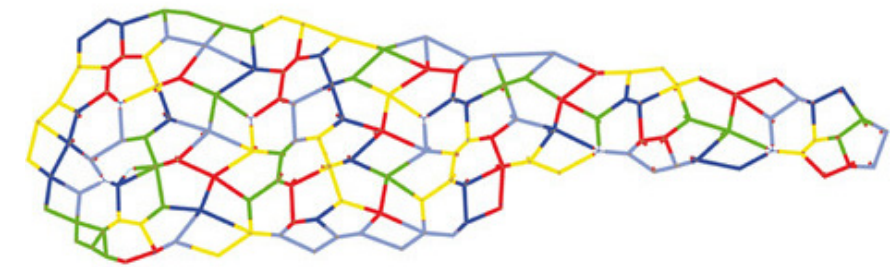
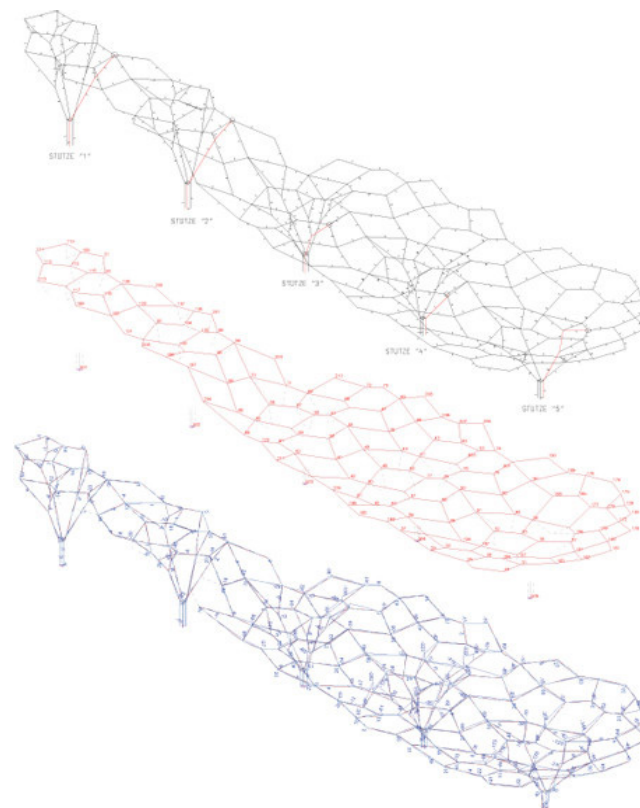
Dougong brackets from China (The Sakyamuni Pagoda of Fogong Temple, 1056 AD) and Japan (Sensoji temple, 628 AD)



typical assemblage of Dougong brackets, can be referred to the Iterated Function System

WestendGate(Marriot Hotel)
Frankfurt, Germany

The canopy takes inspiration from the formation of the branching of a tree. What this project does as well is takes two of nature's structural aspect such as the branching of trees and as well as the pneu system that is represented as the canopy roof. The system also shows the structure as a system that uses multiple columns(Tree trunks) to reach structural integrity, as well as revealing the capabilities of this canopy to grow .



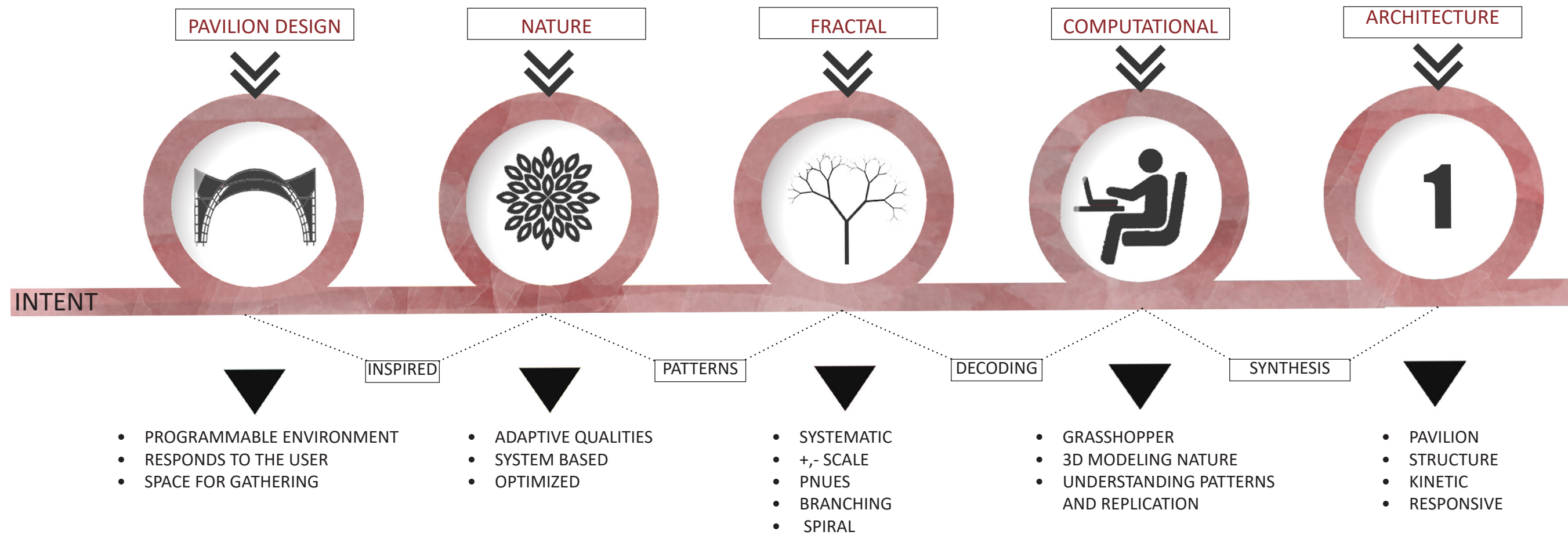
1.3 | PROPOSED PROJECT

A PAVILION OF ADAPTATION

The nature of adaptation in this thesis, which is the focus that this thesis heavily relies on is the exploration of a system that can adapt to the environmental conditions within a given site as well as the social aspects as a place making technique will test and execute a pavilion that can take on these characteristics. “Rather than looking at the more solid incarnations of the architectural imagination, might it not be better to focus on the transient, the willfully temporary and usually quite modest world of the pavilion ?” (Jodidio). The concept of a pavilion, rationales the execution of this fractal adaptive system, pavilions find themselves.

In a world that is temporarily being explored in different locations. In many cases, architectural pavilions set themselves to reveal innovation and technological advancements. This pavilion will encompass the structural qualities that nature offers through the branching of the tree will be the guiding structural influence and as well as the pattern of the pneu configurations by combining both to create a system that can take on the challenge and altering the way we see our built environment from being a static piece of architecture to a dynamic form that executes performative qualities.

the ability to adapt to the environmental conditions of a given location no longer will the solar gain and lighting condition determine the forms spatial configuration. The system will be able to input data and reconfigure itself to the desired thermal conditions as well as ideal lighting condition for the chosen program. The program of exploration will be focused on informal performance and exhibition space as well as create spaces for gathering, The overall goal is to educate the public through formal qualities,



1.3.1 | PROPOSED PROJECT

CASE STUDIES



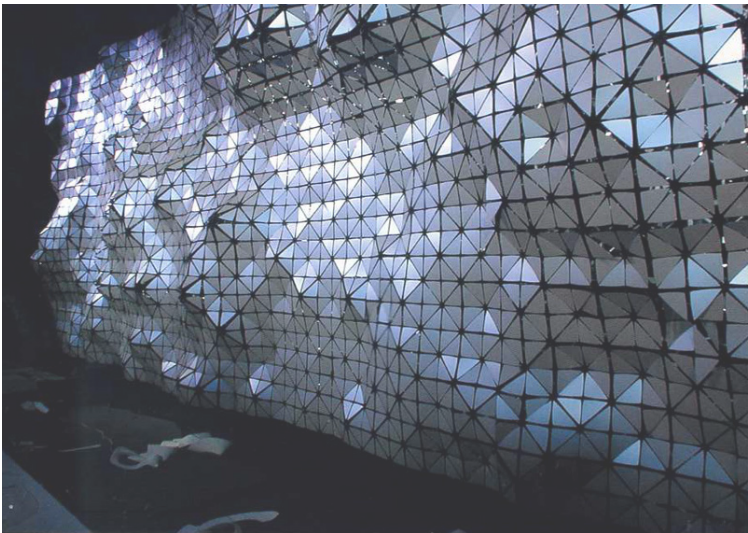
ICD + ITKE Research Pavilion

This exploration of the simplistic method of the reputation of geometry through the increasing and decreasing of scale, with the additional focus on the joinery systems that can be applied brings out innovation in both form finding as well as computational design.



Serpentine Pavilion
Summer house 2016

This case study outlines the characteristics of a pavilion that shows the modular stacking formation to create form. This system has the functionality to have adaptive qualities through the incremental growth of each individual cell.



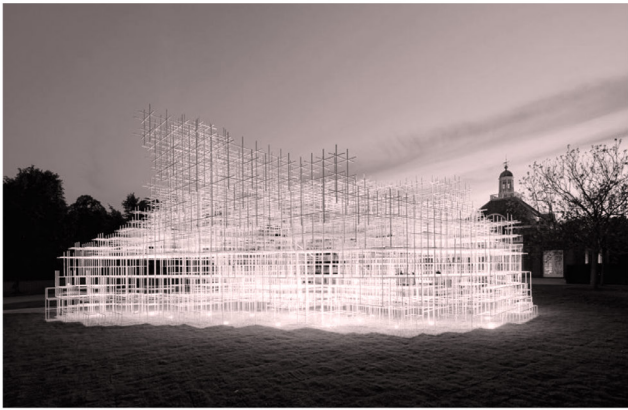
Aegis Hyposurface

The study done in this system is referred to the mechanical aspects of a wall. The system has the capability to respond to the environment, this system is more so in conjunction with the social as the reactive portion as one can begin seeing an action and reaction system. This system is adaptive to the user in a push and pull movement learning from the mechanics and sensors can bring forth design executions based on this kinetic system.

BARCELONA PAVILION



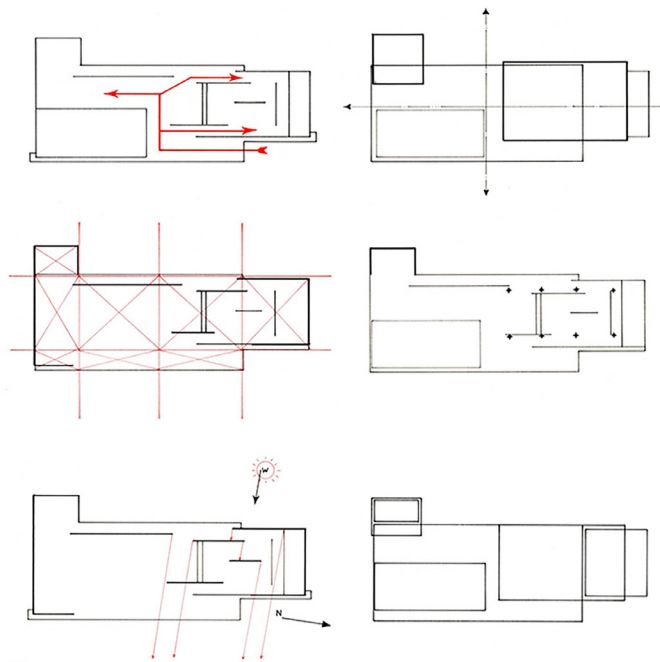
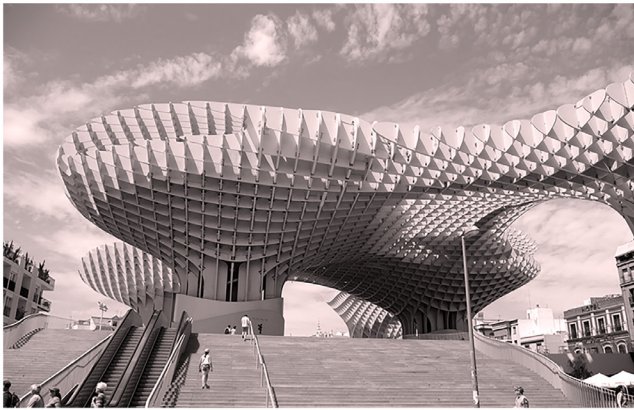
SERPENTINE GALLERY 2013



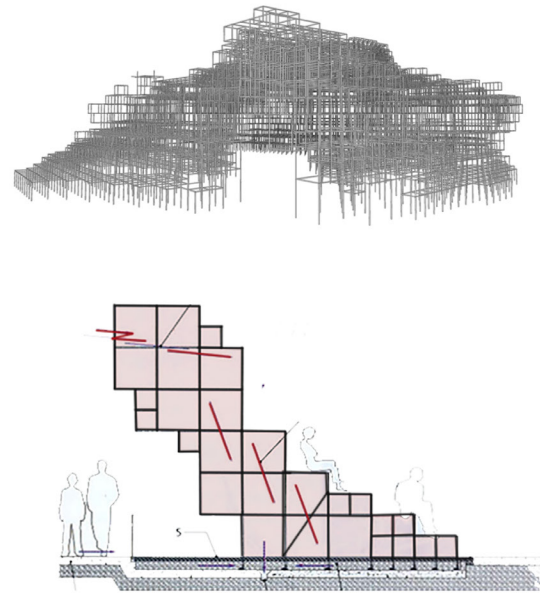
DANISH PAVILION



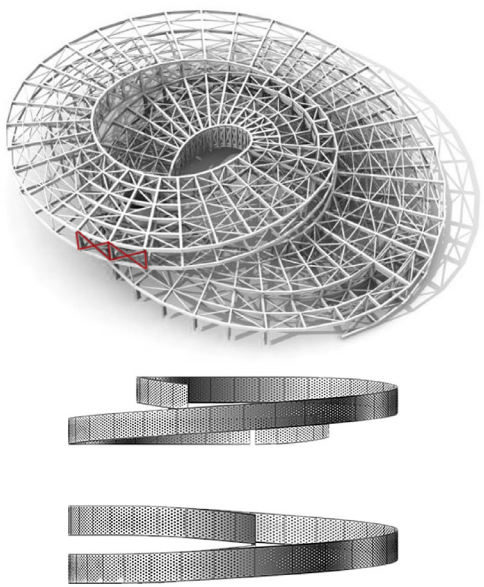
METROPOL PARASOL



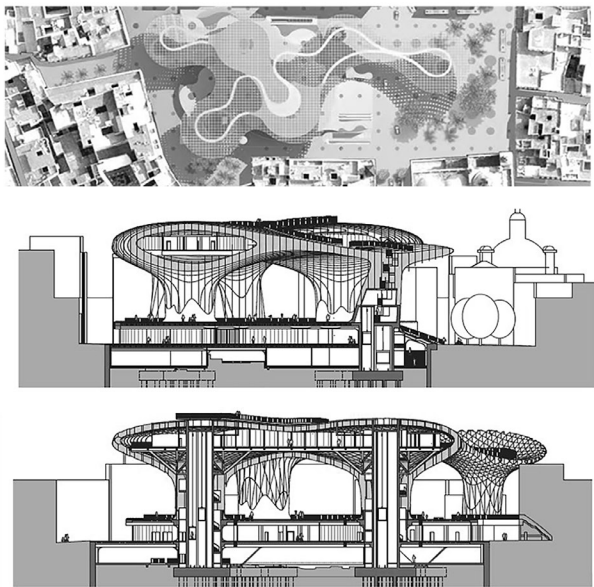
CIRCULATION ANALYSIS



CREATING SPACE WITH MODULES



SPIRAL ENCLOSURE



COMMUNITY GATHERING

2.1.1 | SITE SELECTION AND SIGNIFICANCE

Significance

Piedmont park sits on a total of 182 acres of land in the center of Atlanta's thriving downtown. The park serves as a place of peace in a city that is full of life, where someone can have a picnic or stroll through the park's lush green spaces and enjoy nature in an urban environment. The park frames beautiful views of the city's skyline from multiple points. Piedmont park showcases the coined phrase "Atlanta, a city in a forest". It serves as a medium between the natural and man-made.

The park's open green spaces and multiple pedestrian and bike paths, give access to the Atlanta Beltline highlighting the programmatic nature of the park. The park serves many purposes like music festivals, farmers markets, botanical gardens, weddings, art exhibition, local vendors, and much more. The park has many attributes, but on this 182 acres of land, the park lacks a public structure that can create a sense of enclosure, a place of rest, and a piece of architecture that does not take away from the park's natural beauty but one that takes on the adaptive qualities of the park.



2.1.1 | SITE SELECTION AND SIGNIFICANCE

Piedmont Expansion Atlanta, GA

The city of Atlanta announced in December 2017 that the city will be allocating \$20 million to the expansion of Piedmont Park. The expansion will give the park a new northern entrance located on the intersection of Piedmont Drive NE and Monroe Drive, which will replace privately owned properties at the entrance of the site. The expansion will introduce a new entrance to the beltline, plus additional access to the rest of the park. The intent is to increase park access to the city’s residents. Currently, 64% of the resident within half mile walking have access to public parks. This expansion will considerably increase that number. The new development will introduce new bike paths and pedestrian trail and as well, opening up green spaces.

The conceptual design done by landscape architecture firm HGOR shown in Figure 00 shows new trails and bike paths. The design gives a new life to a portion of the park that has not seen much activity. The design additionally showcases the prospect of a pavilion on this new expansion.

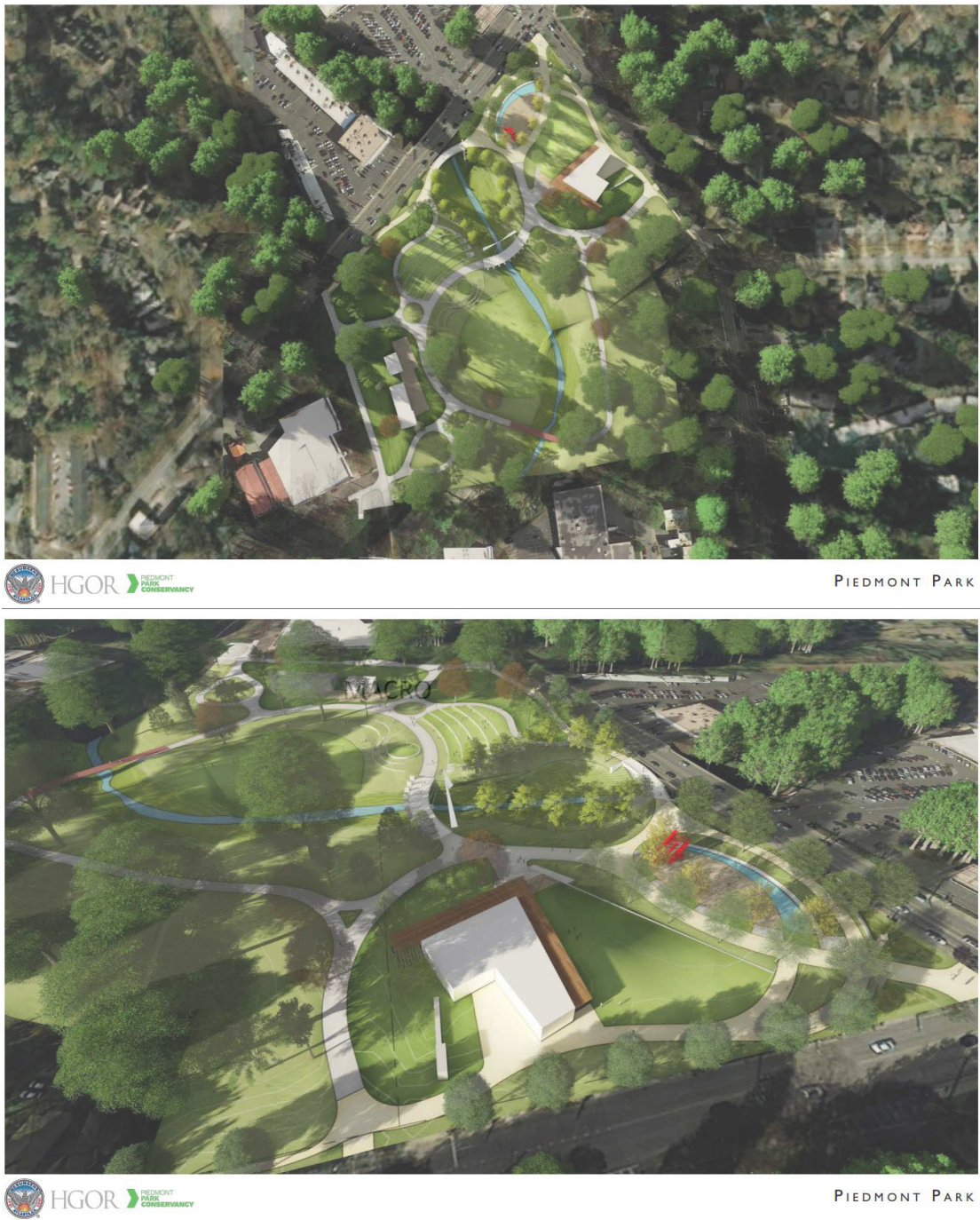
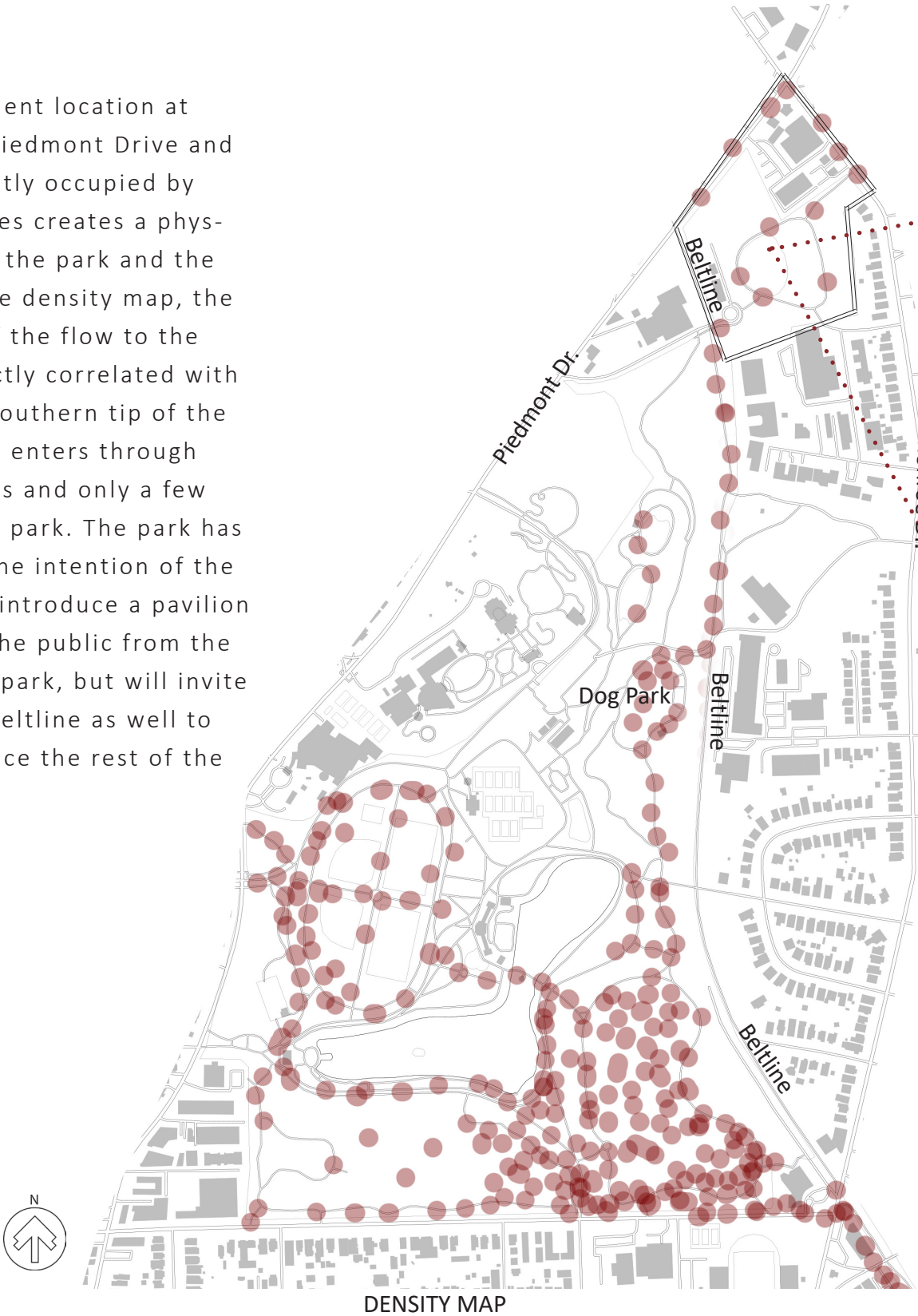


FIGURE 00_CONCEPTUAL SITE

2.1.2 | Existing Site Conditions

The future development location at the intersection of Piedmont Drive and Monroe Drive currently occupied by commercial properties creates a physical barrier between the park and the public. As seen in the density map, the main contribution of the flow to the Piedmont park directly correlated with the beltline on the southern tip of the map. The public that enters through the beltline disperses and only a few make it pass the dog park. The park has an uneven flow, so the intention of the expansion is also to introduce a pavilion will not only invite the public from the northern end of the park, but will invite people in from the beltline as well to continue to experience the rest of the park.



CURRENT SITE CONDITION

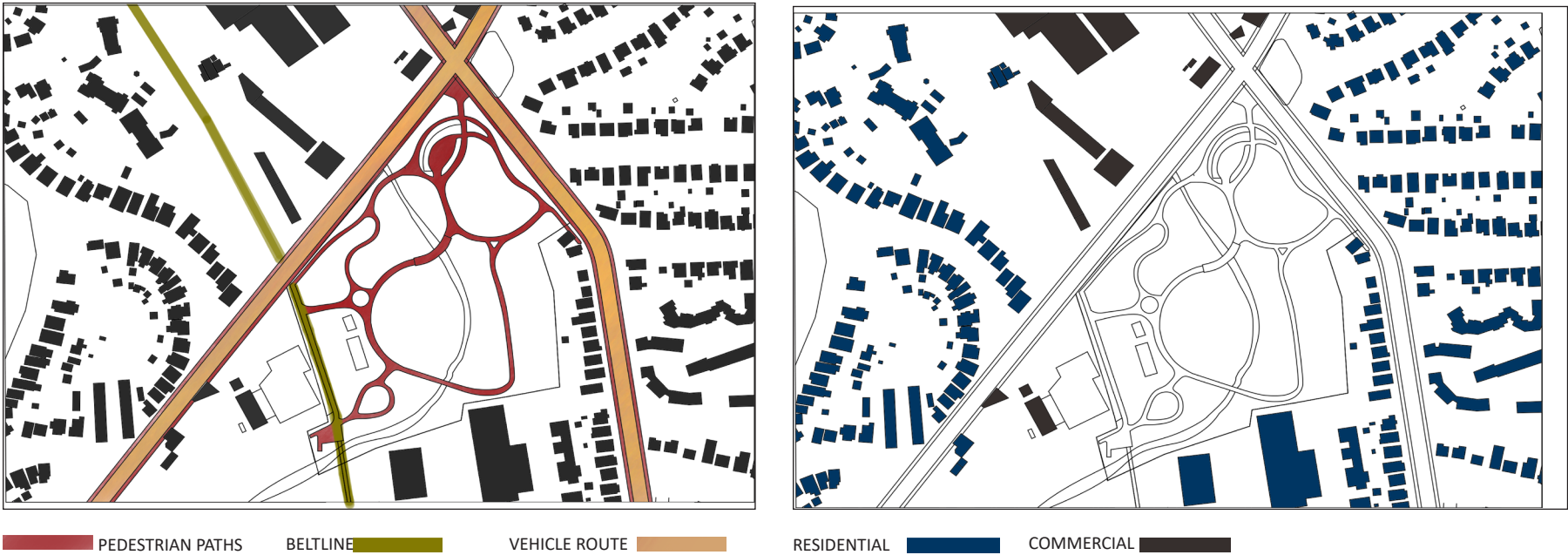
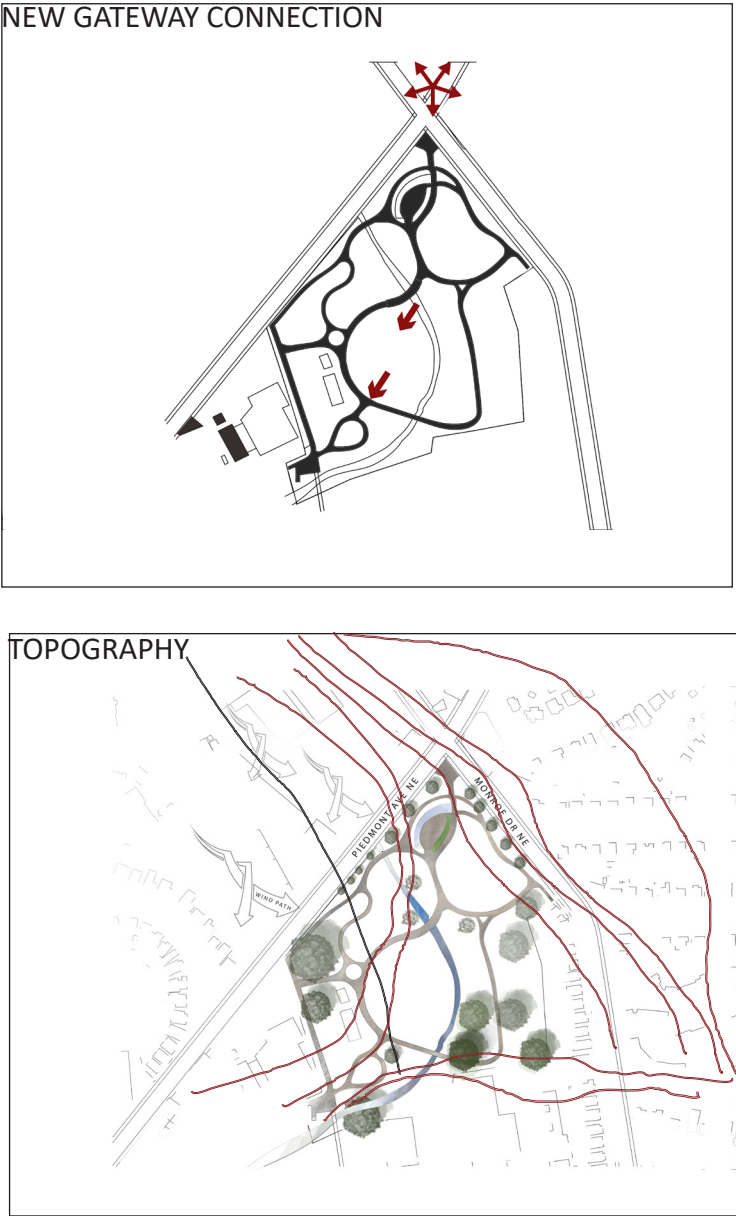


2.1.3 | SITE ANALYSIS

PROPOSED MASTER PLAN
As seen through the site plan at a micro scale. The pedestrian paths and landscape, the environment creates new node to piedmont park.



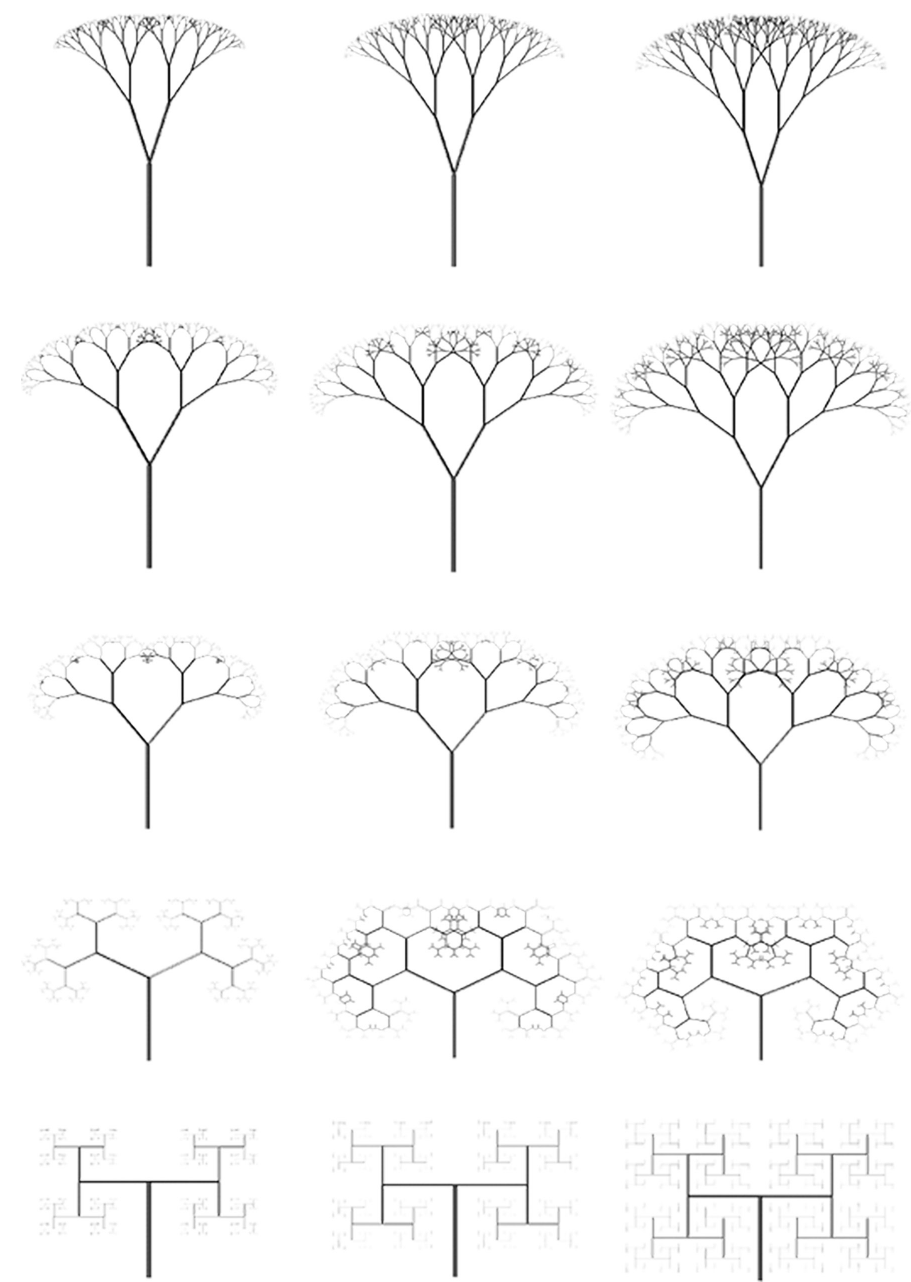
2.1.2 | SITE ANALYSIS



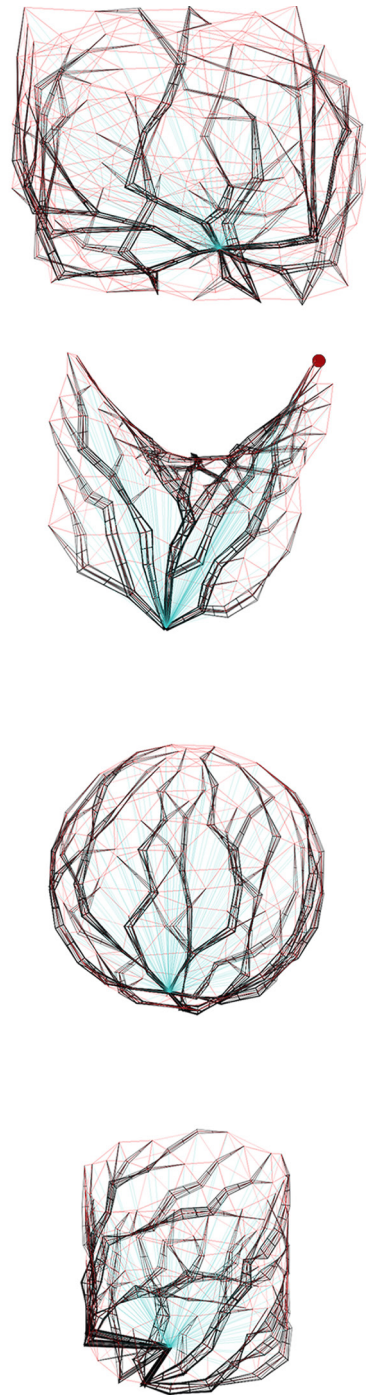


3.1.1 | DECODING FRACTAL BRANCHING

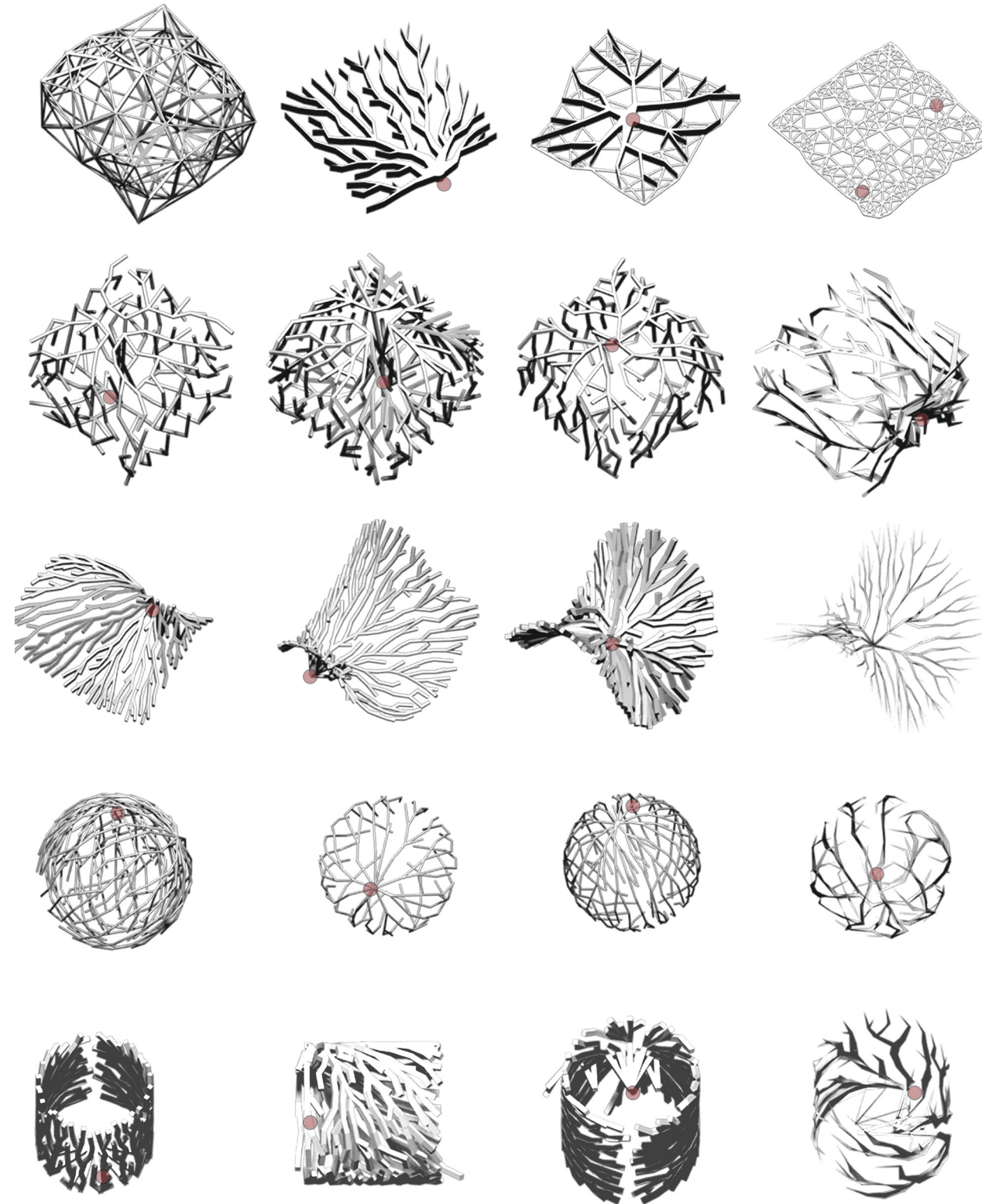
Trees with their branches are one of the finest examples of nature's fractals that are self-similar in pattern and highly irregular. There are different explanations about the tree's fractal-like branching appearance from different angles of disciplines such as biological, structural and mechanical. However, the basic explanation is functional need .The total length of all branches and stems, are uniform in energy utilization



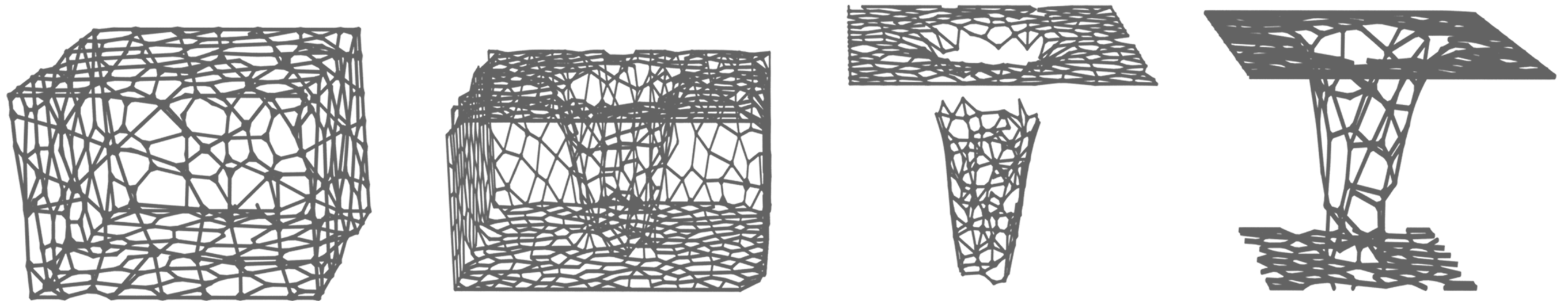
SYSTEM APPLIED TO GEOMETRY



SHIFTING POINTS OF ORIGIN



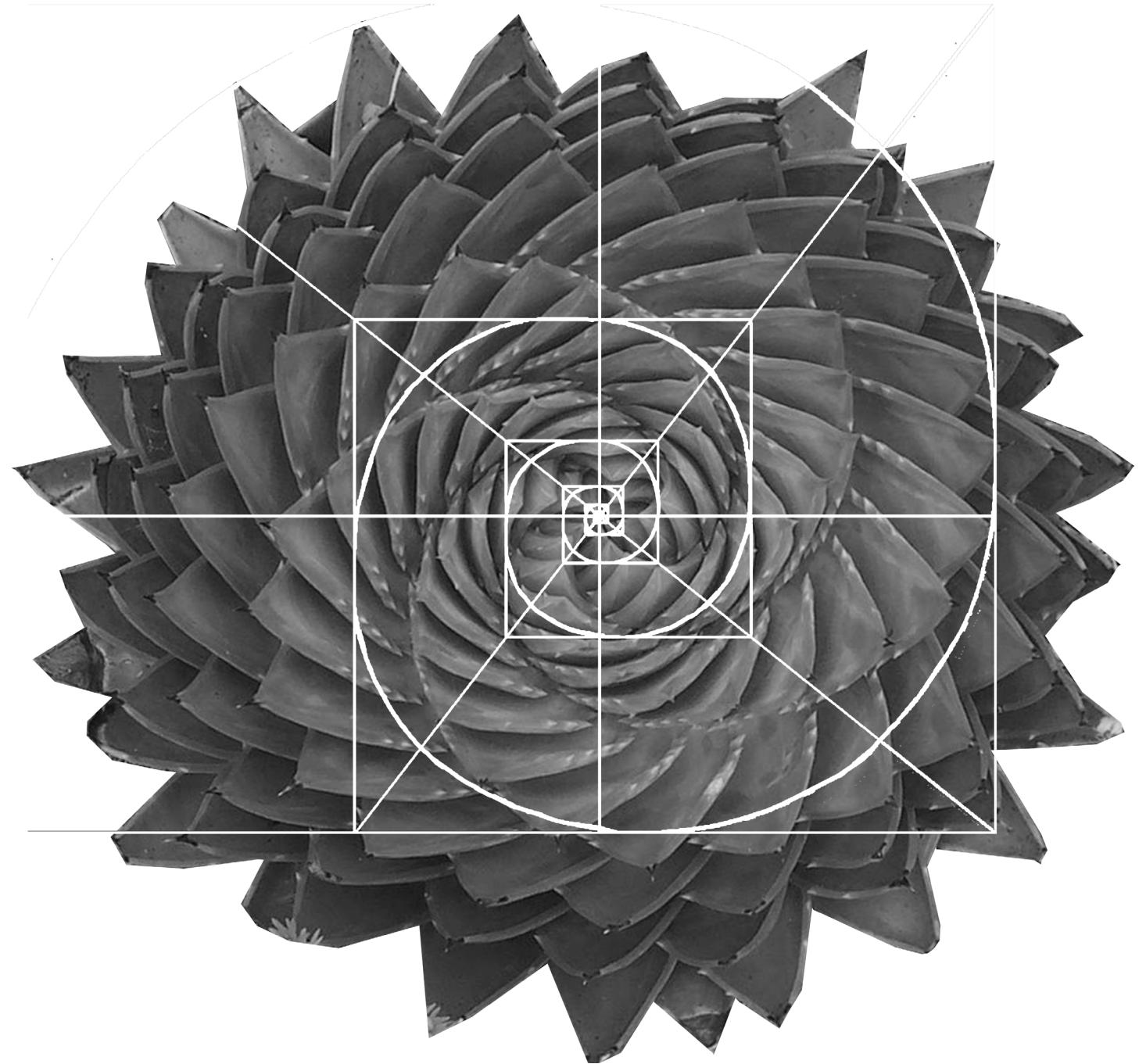
This process integrates the fractal pattern to a more structural concept. It lead to the exploration of creating closed loops to create a structure that can adapt to a form and have a sense of enclosure as well as structural rigidity.



3.1.2 | DECODING SPIRAL FRACTALS

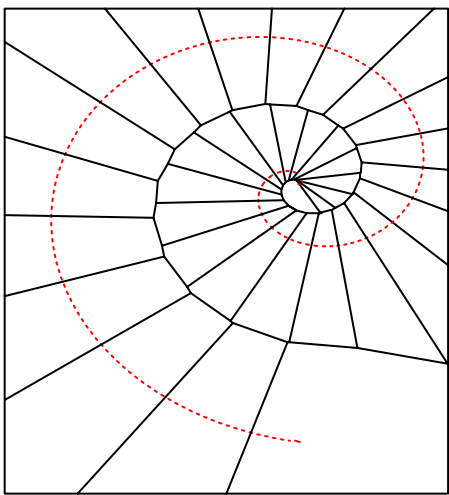
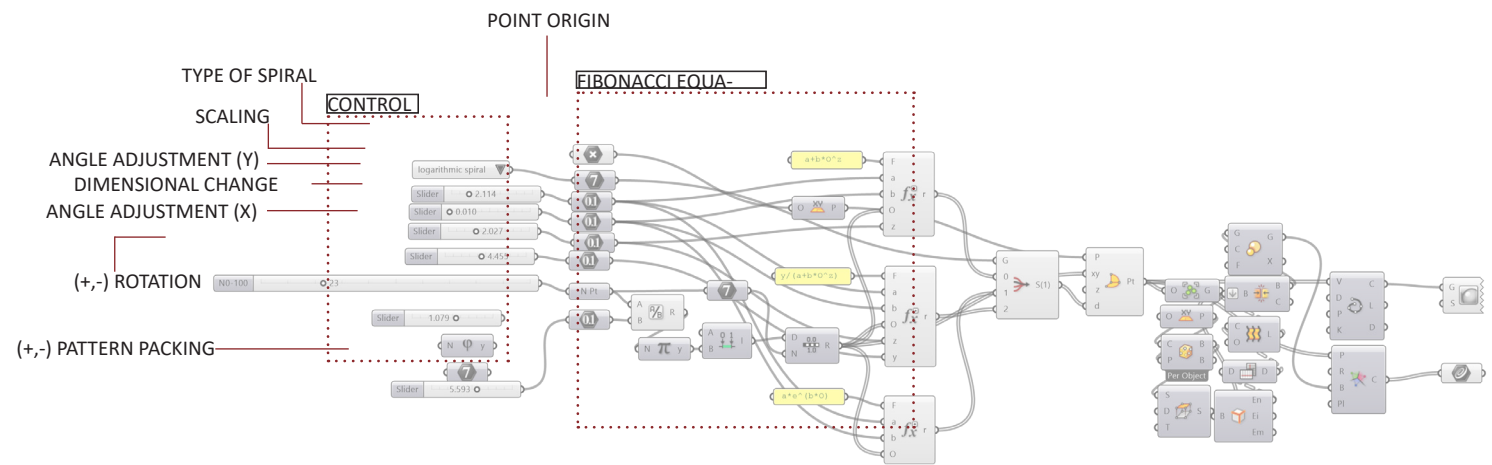
The Agave Cactus fully encompasses the three major natural phenomena as shown in the previous section. The Fractal system in the leaves of the plant grow in the most efficient patterns which can be seen as a pnue (Closest Packing). This system takes the most efficient route to grow, giving each leaf the right amount of space to grow.

The Cactus thrives on the fractal qualities of dimensionality by increasing or decreasing in scale to create the form, which in turn gives new possibilities to the adaptive qualities of creating space. The main distinction of this system, in comparison to fractal branching, is the plant follows a rule and can be predicted in its growth. The principle this uses system to obtain its is the Golden Ratio. This opens up the possibility of control and in essence, a methodology to recreate this system at a computational level.

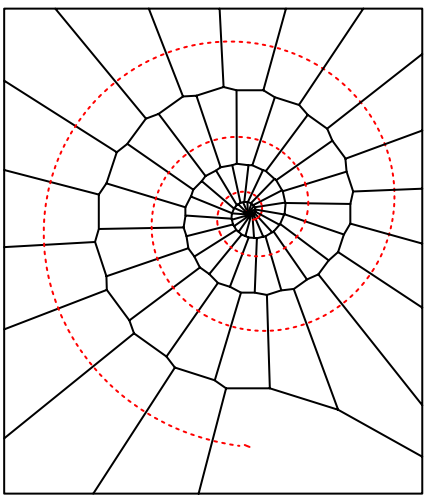


CONTROL THROUGH COMPUTATIONAL DESIGN

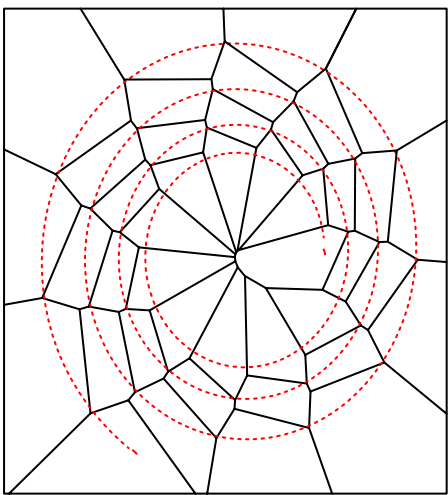
This exploration of a spiral fractal focuses on trying to achieve the spiral patterns seen in an agave cactus, through computational design. The process seen in the diagrams below go through the phases of transformation. The control location in this process uses the Golden Ratio curve, seen in red, to create a path for the 2D pattern to follow. The progression of the pattern is similar to fractal branching. However, instead of achieving closet point, the system has a set of parameters. In this case, it would be the rectangle. The geometry is told to follow the curve but simultaneously have the ability to reconfigure and re-adapt so it fills the space.



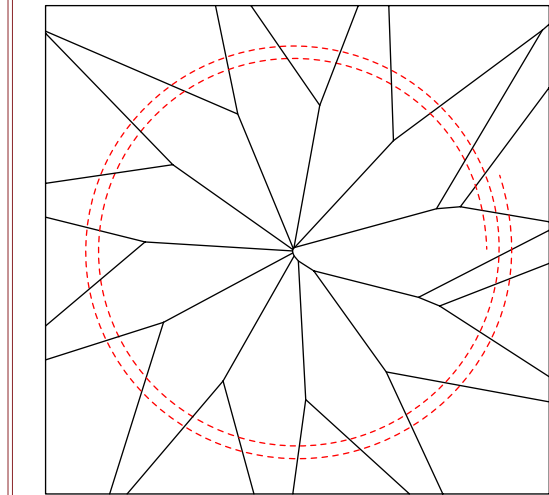
ANGLE ADJUSTMENT (Y)



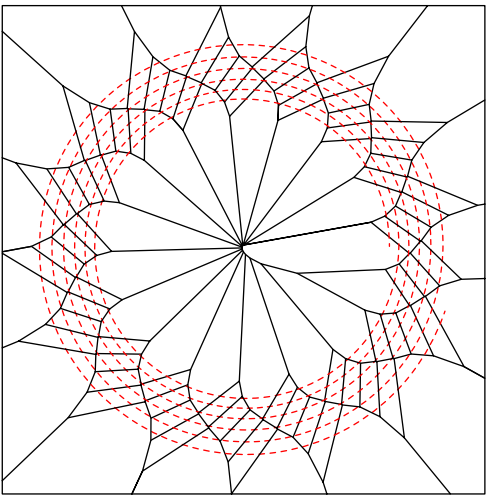
(+) ROTATION



(+,-) ROTATION



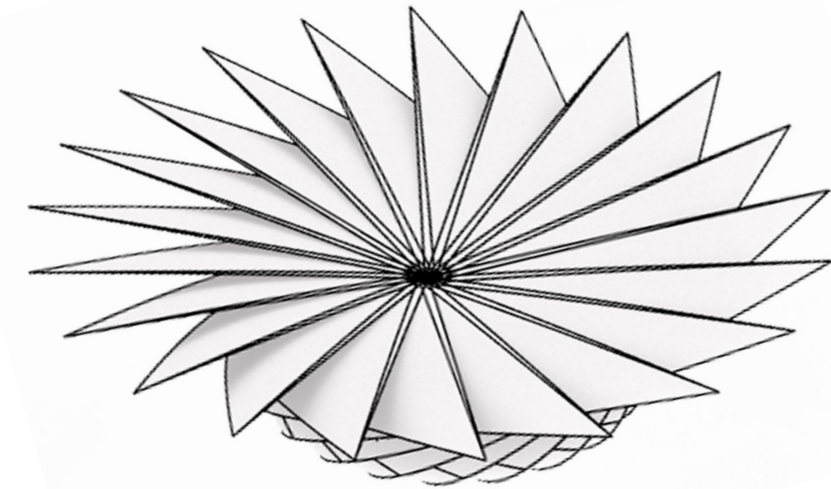
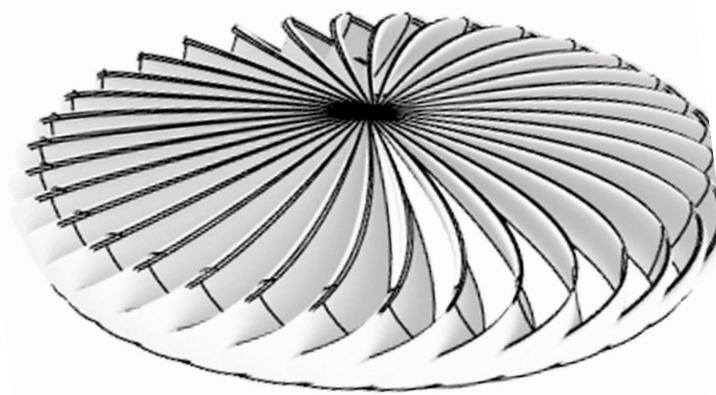
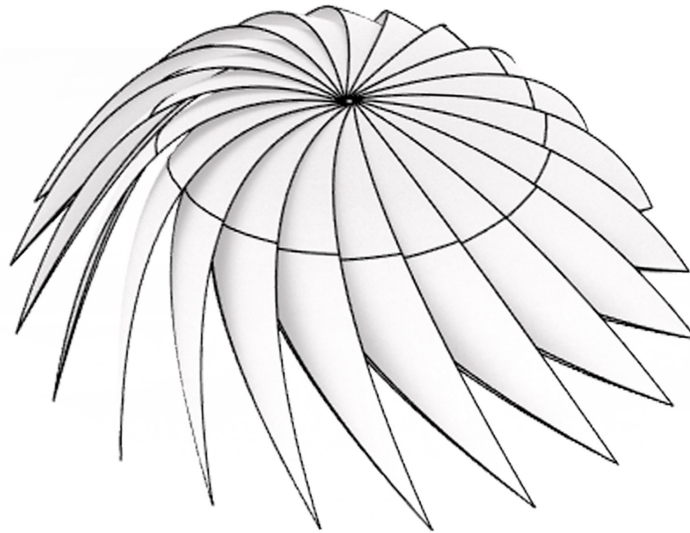
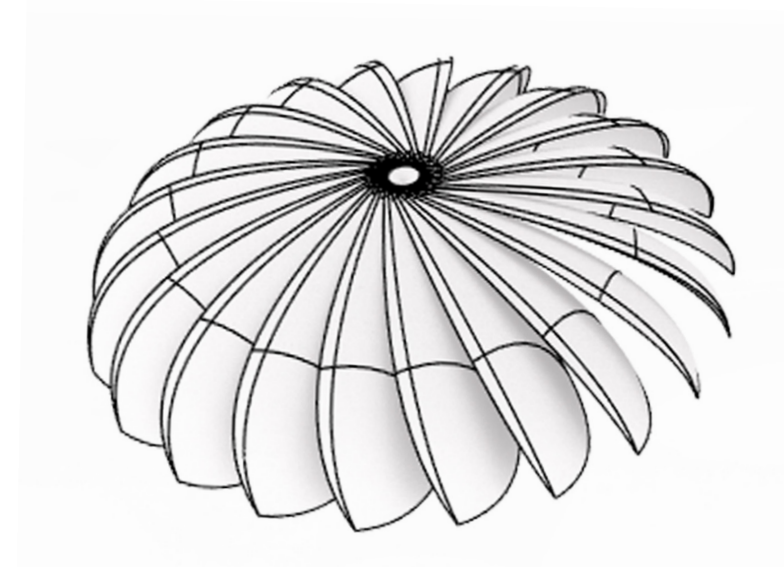
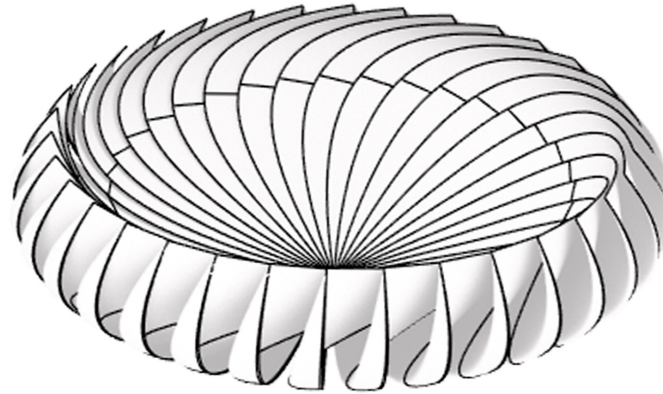
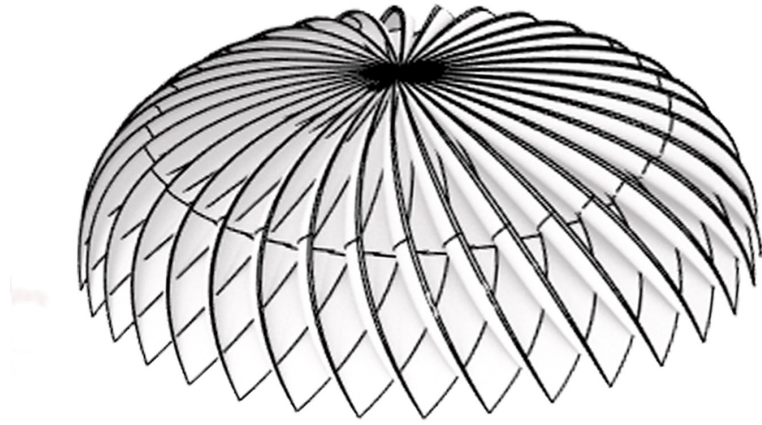
ANGLE ADJUSTMENT (Y)
(-) ROTATION



ANGLE ADJUSTMENT (Y)
(+) ROTATION

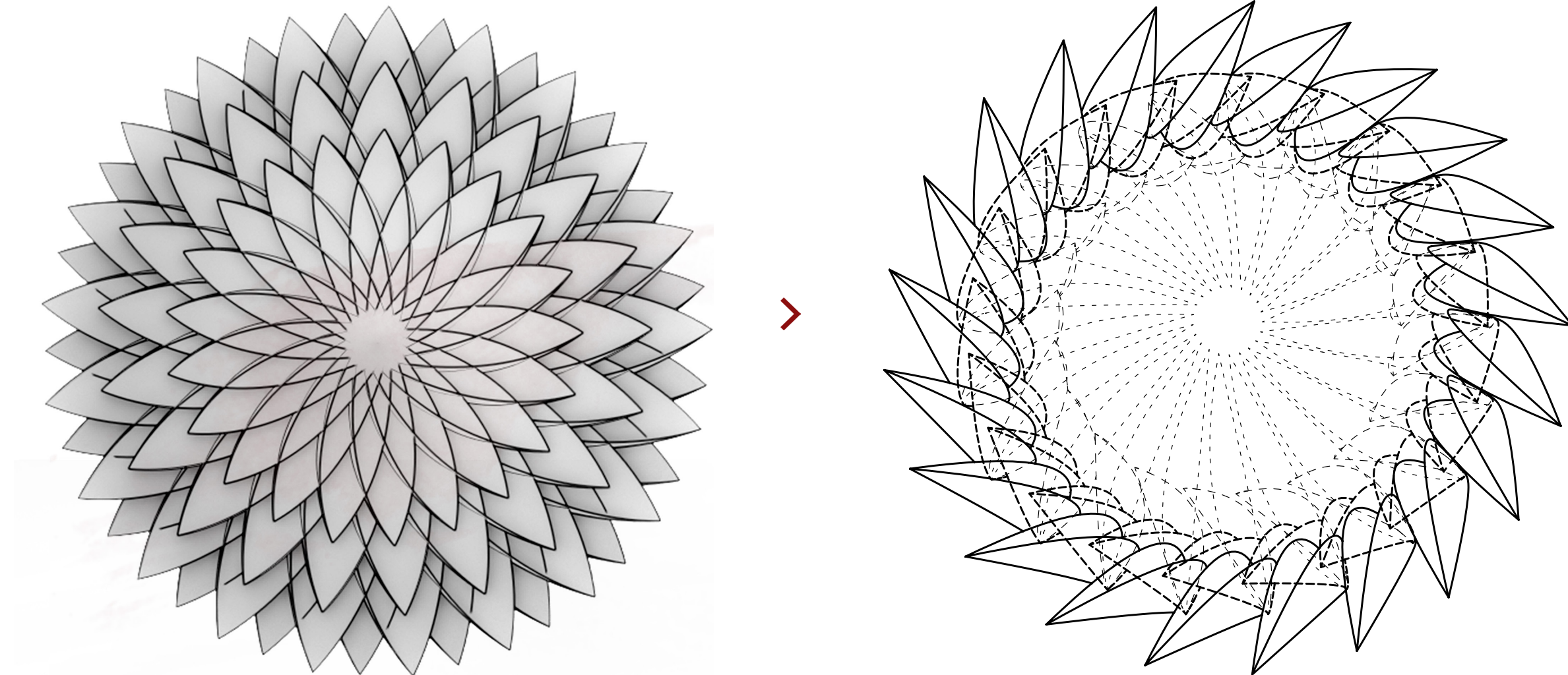
FROM PATTERNS TO FORM

The exploration done in the diagrams below create a series of test that bring the two dimensional diagrams seen previously to a more formal quality. This system brings out the qualities of form and order, and the emerging qualities of a pavilion.



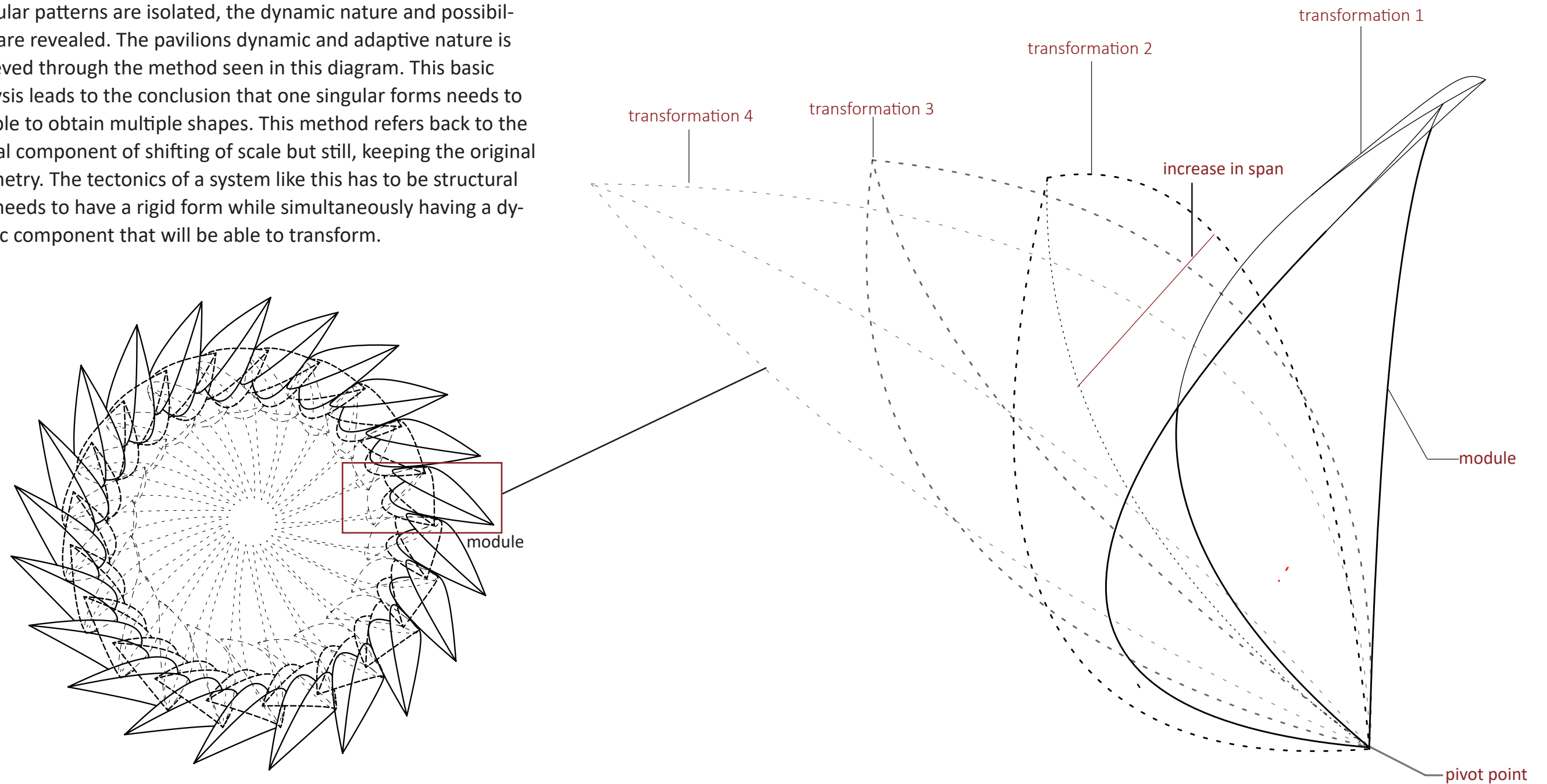
Dynamic form

The attributes of a spiral fractal lead to the understanding of movement. The replication process seen below gives the form a new understanding of adaptation. The system follows the same guiding principle, that it can be manipulated through the controls outlined previously.



Modular Form

The modular formation of this plant like structure is the key component that creates this dynamic system. This form opens up the opportunity for the system to be customized. When the individual modular patterns are isolated, the dynamic nature and possibilities are revealed. The pavilions dynamic and adaptive nature is achieved through the method seen in this diagram. This basic analysis leads to the conclusion that one singular forms needs to be able to obtain multiple shapes. This method refers back to the fractal component of shifting of scale but still, keeping the original geometry. The tectonics of a system like this has to be structural and needs to have a rigid form while simultaneously having a dynamic component that will be able to transform.

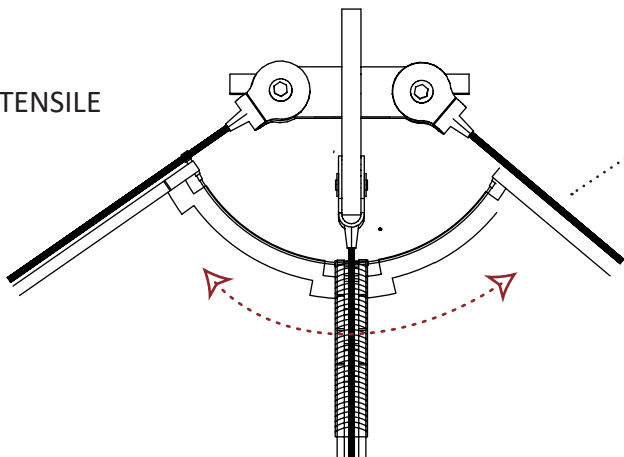


3.2 | TECHNIQUE AND TECTONICS

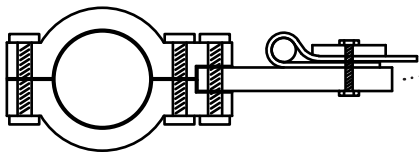
TENSILE STRUCTURE

The tectonics of a system that has dynamic form but needs rigidity and structural capabilities, but simultaneously adapts to dynamic components, which allow for transformation best describes the features of a Tensile Structure.

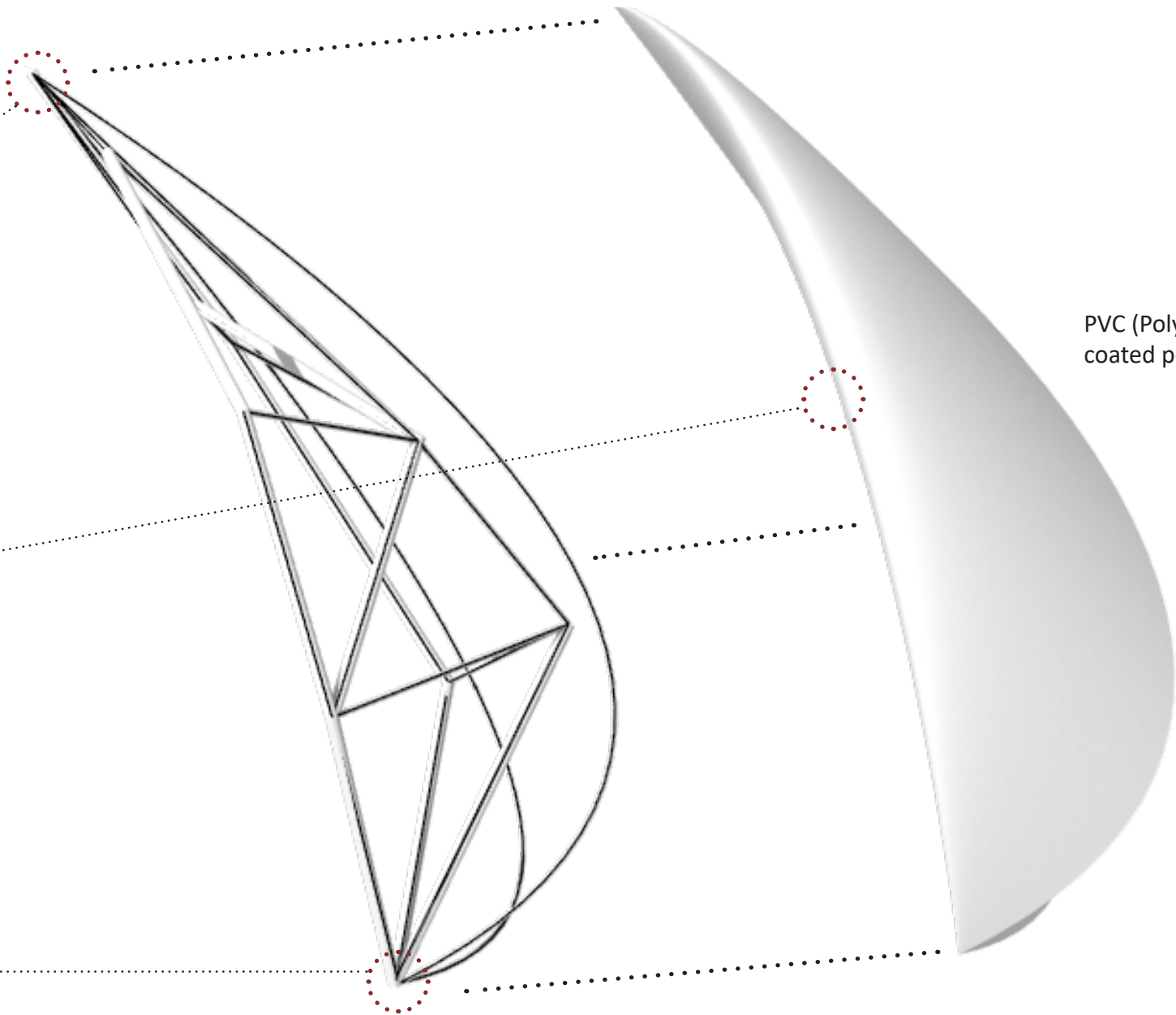
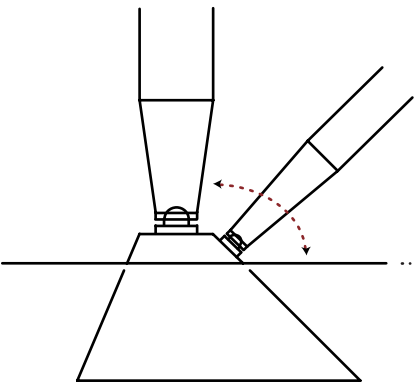
MANEUVERABLE TENSILE CONNECTION.



FABRIC CONNECTION TO THE STRUCTURE

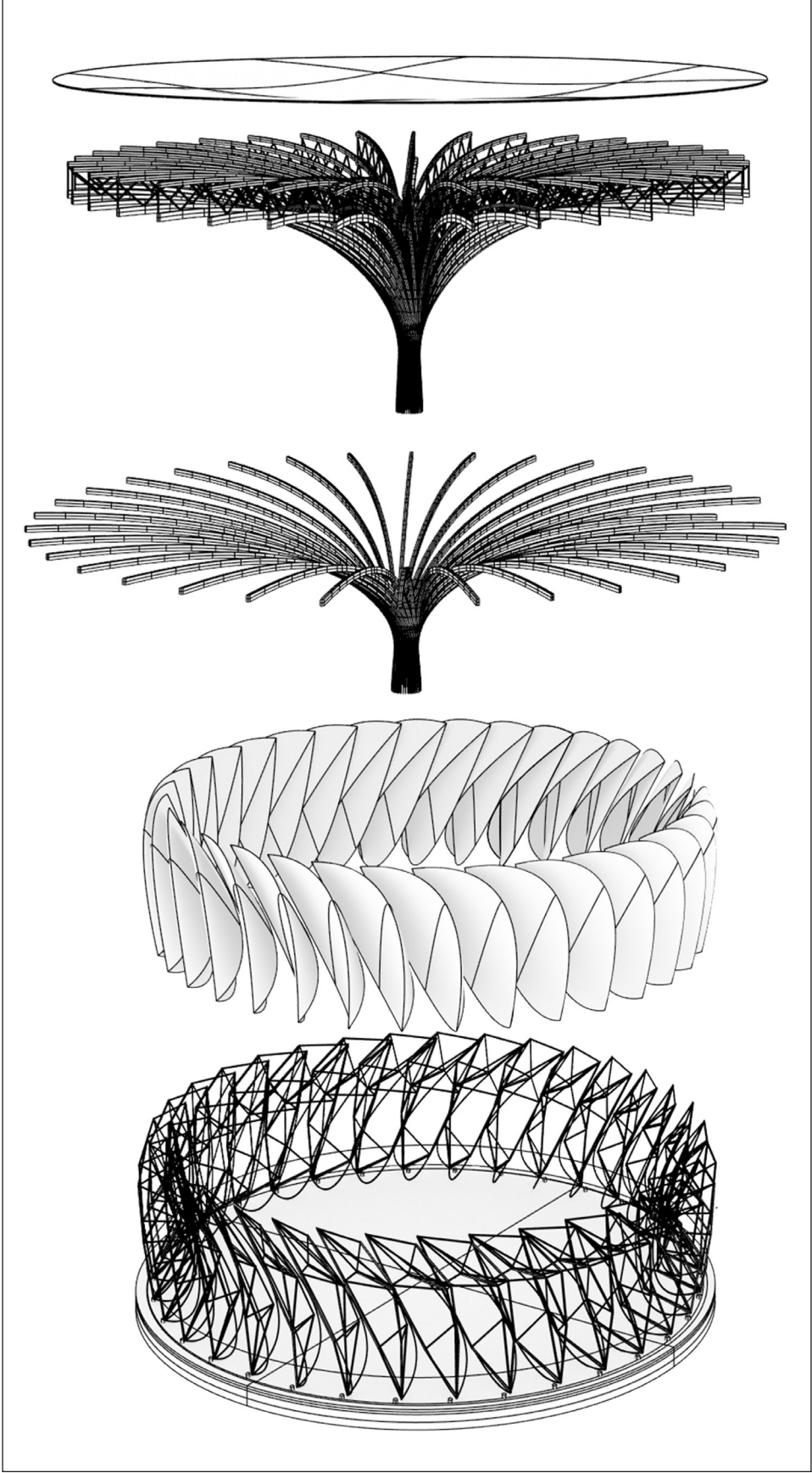


FLOOR MOUNT GIVES ROTATION TO PIVOT POINT

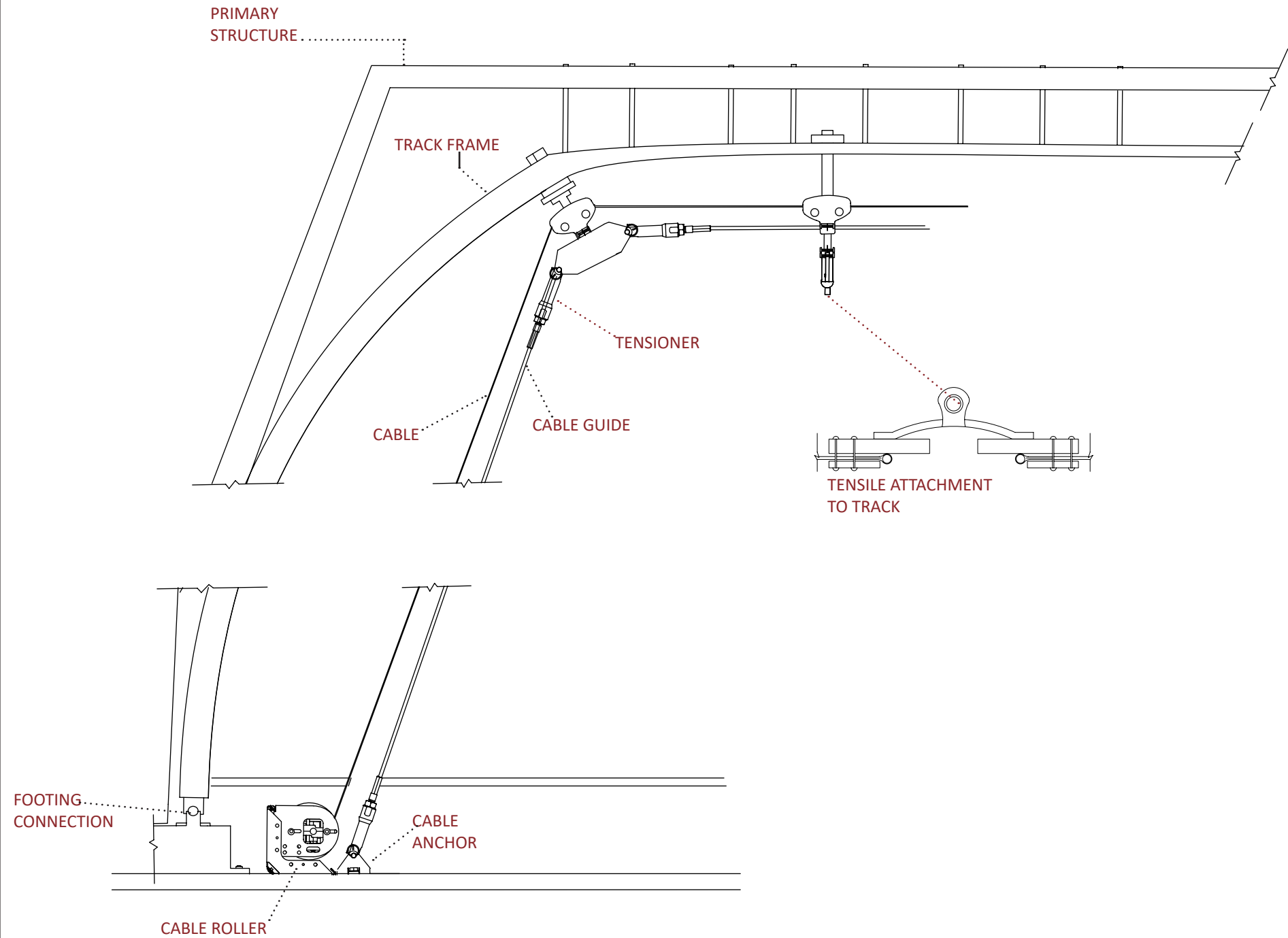


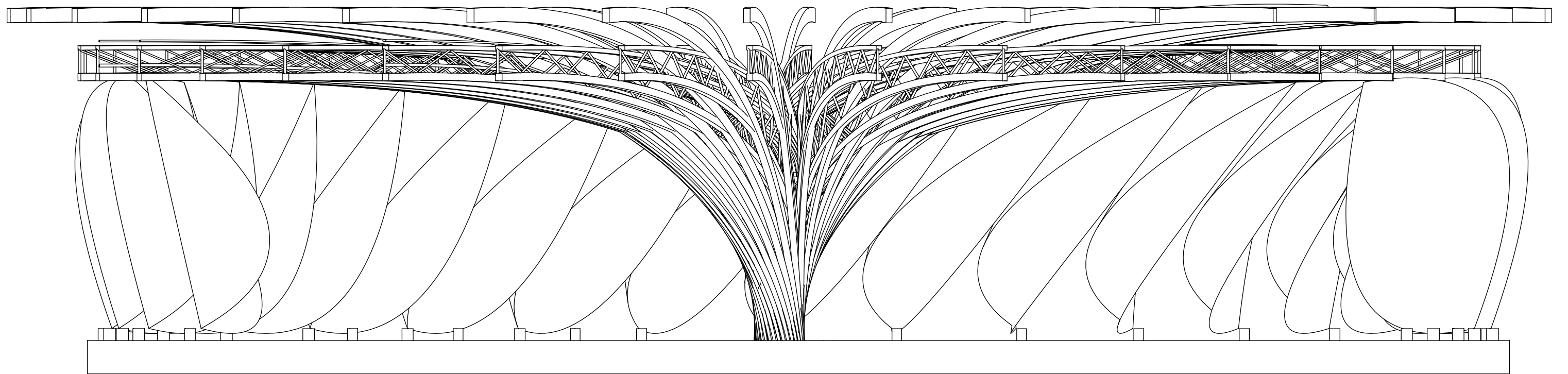
PVC (Poly Vinyl Chloride) coated polyester cloth

EXPLODED STRUCTURAL ASSEMBLY

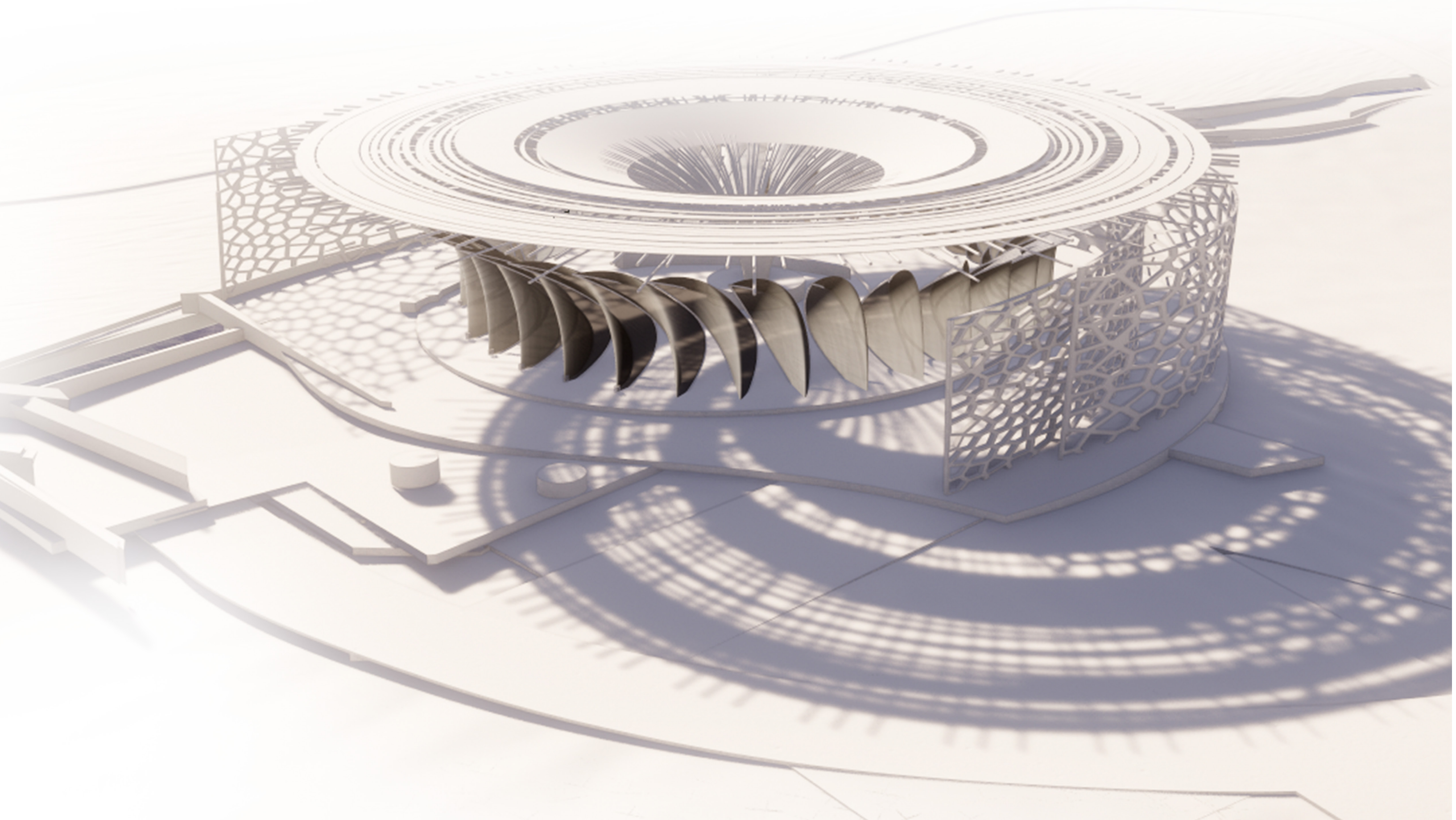


CABLE GUIDED TRACK SYSTEM





4.0 | DESIGN INTEGRATION



SITE CONTEXT

The understanding of the site needs in reference to the park lacks a public structure that can create a sense of enclosure a place of rest, a piece of architecture that doesn't take away from the parks natural beauty but a structure that takes on the adaptive qualities of the park.

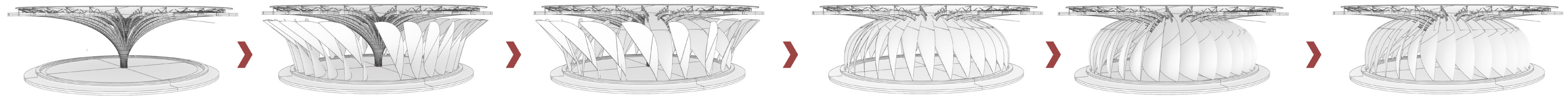
The formal language of the pavilion, since inspired by natural patterns of exploration the pavilion keeps the natural beauty of the park, with its fabric lightweight skin and structure directly influenced by tree formations

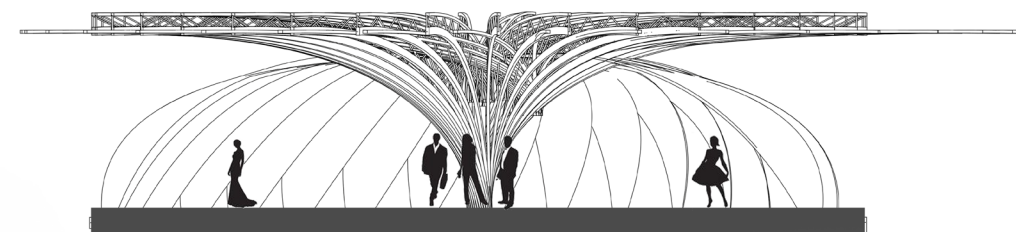
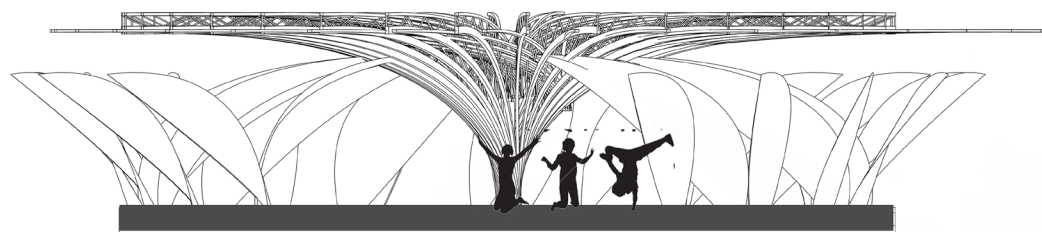
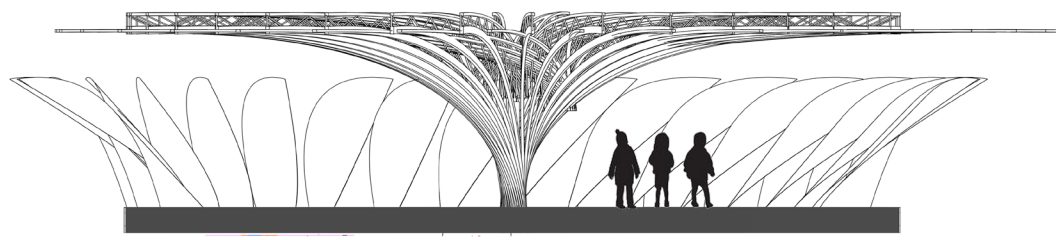
The location of the pavilion was based off the movement of people in the park, keeping the pavilion at a central location on the expansion, will attract not only the primary goal (residents North of the park), but as well allow for the movement and exploration from the beltline to the new public space.



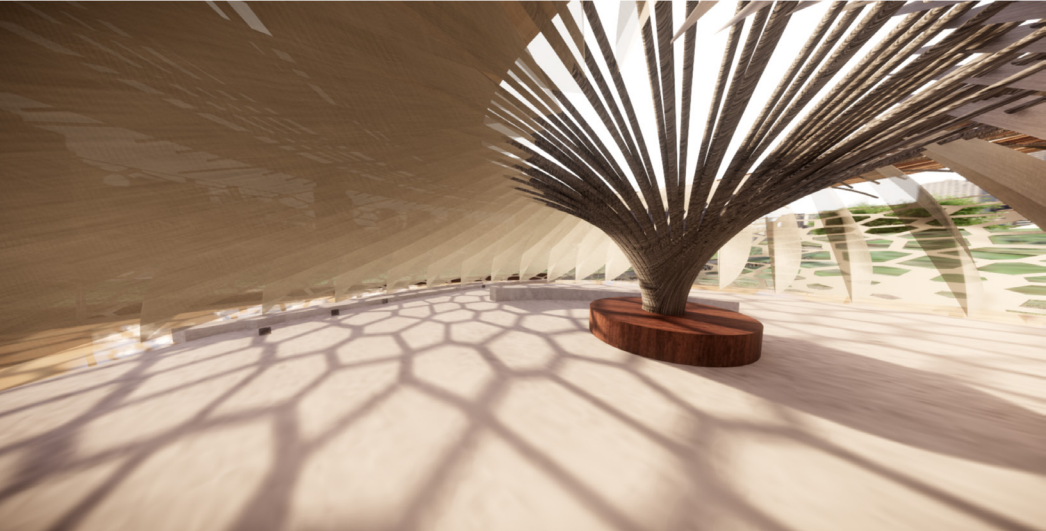
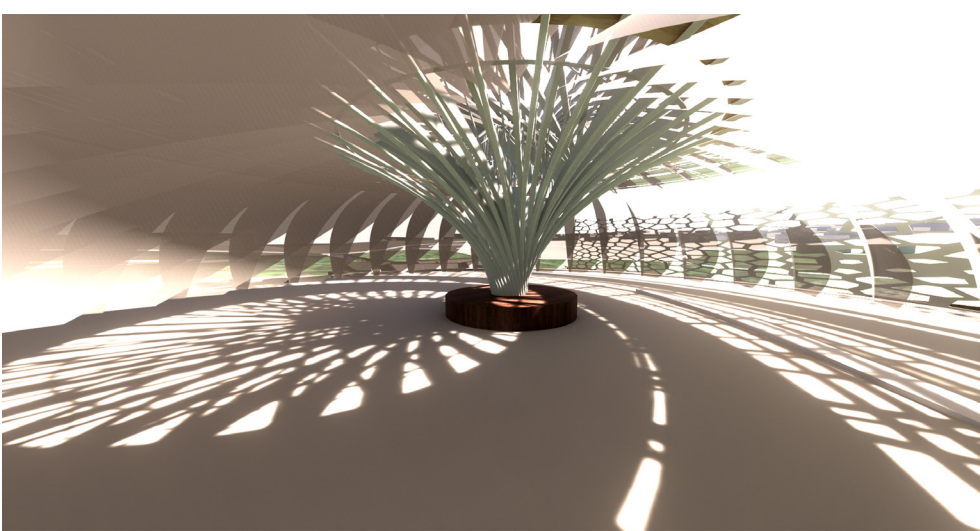
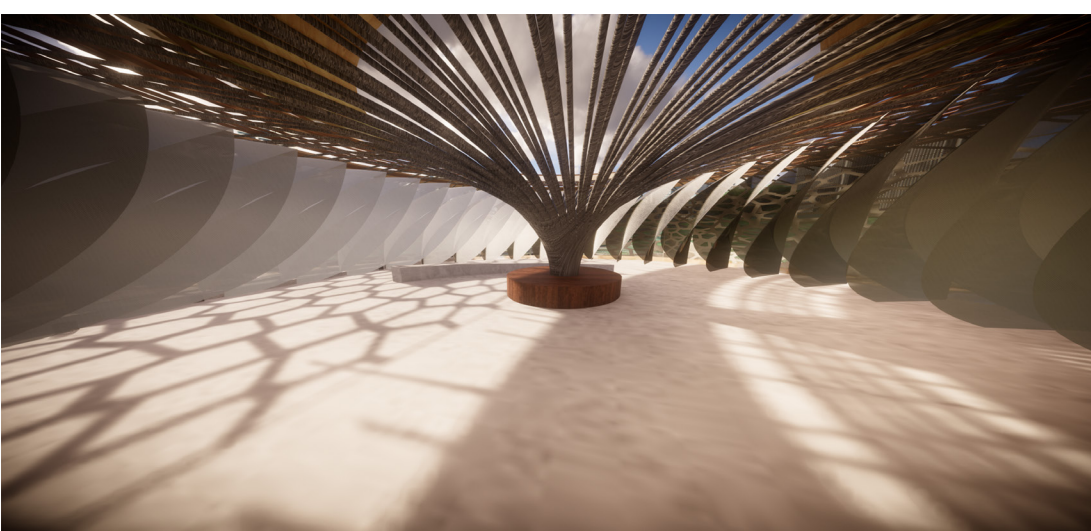
The series of diagrams below represent the control of enclosure which allow the pavilion to become part of the landscape, seamlessly transforming from the interior to exterior and vice versa.

The pavilions intent was left to the interpretation of the user. It is focused on providing a space where the program was not necessarily pre-determined. Rather, it introduces the idea that the public can create a program that is now integrated into the adaptive environment.





LIGHTING CONDITION_INTERIOR



PIEDMONT PAVILION

A PAVILION INSPIRED BY NATURE

CONCLUSION

The objective of this thesis was to add to the discourse that architects have had with their built environment, and how to adapt to these fluctuating parameters and condition that society is constantly in. This thesis took on these parameters and questioned the systems of a wall, ceiling column and defined them to be truly one cohesive piece of architecture. That is when the architecture goes merely from a shading device to a system that begins to adapt to take on the attributes

of a dynamic system. To successfully complete this objective the research consisted, look at nature as a source of inspiration, in particular, the adaptive qualities that nature provided through fractal patterns. The use and understanding of the fractal patterns at a computational level. The process of understanding assisted in the formal qualities of a pavilion, concluding with a unified form that integrates a dynamic structure to qualify as an Architecture of Adaptation.



5.0 | FINAL BOARDS

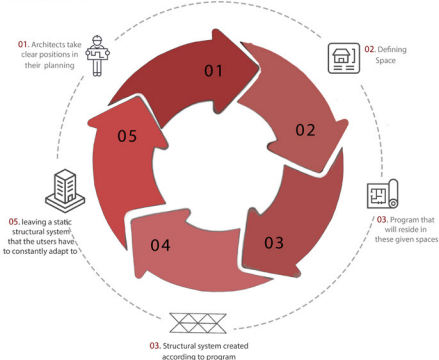
ARCHITECTURE OF ADAPATATION
STRUCTURE IN NATURE

STATEMENT

The concept of a piece of architecture taking on adaptive qualities is based on the ability that a system can effectively respond to the environment and the evolving programs. Architects strive to create designs that respond to external changes, creating a challenge with kinetic and the immovable aspects of a building, which can be identified as the systems of walls, ceilings, and columns. This system however, creates the foundation of a successful built environment but also hinders the adaptive and flexible qualities. These systems are implemented permanently and confined to the site and program that has been defined to them. Keeping this challenge in mind, one cannot help to see nature and be inspired by the adaptive and the systematic qualities that nature constantly is using, from the fractal branching of a tree to the efficient way of filling space in a honeycomb. We can start seeing a trend in nature and the adaptive qualities it tends to. Nature does not create form without a function.

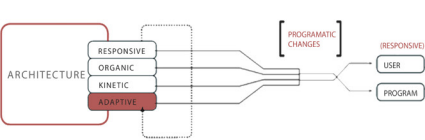
This thesis investigates the discourse that architects have had with the adaptive qualities of architecture by taking inspiration from nature as a design strategy. The project instantiates this notion into a pavilion that is programmed for informal performance and exhibition space. This pavilion will test out the performative qualities by responding to the exterior environment and the evolving nature of the program, concluding with a system that will bring forth a refined appearance all in one single configuration.

CONCEPT

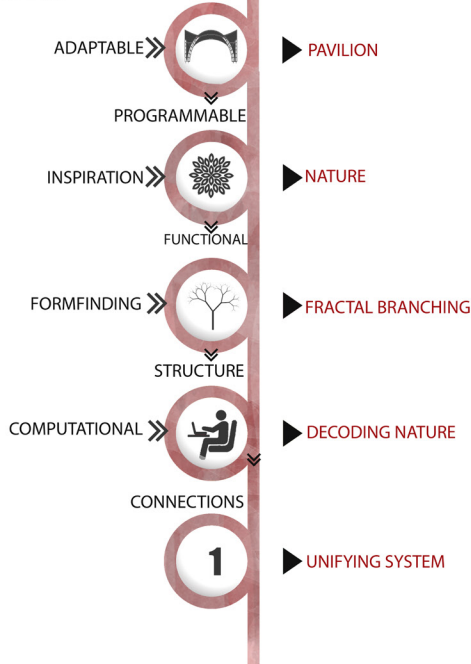


This thesis investigates the discourse that architects have had with the adaptive qualities of architecture by taking inspiration from nature as a design strategy. The project instantiates this notion into a pavilion that is programmed for informal performance and exhibition space. This pavilion will test out the performative qualities by responding to the exterior environment and the evolving nature of the program, concluding with a system that will bring forth a refined appearance all in one single configuration.

OBJECTIVE



INTENT

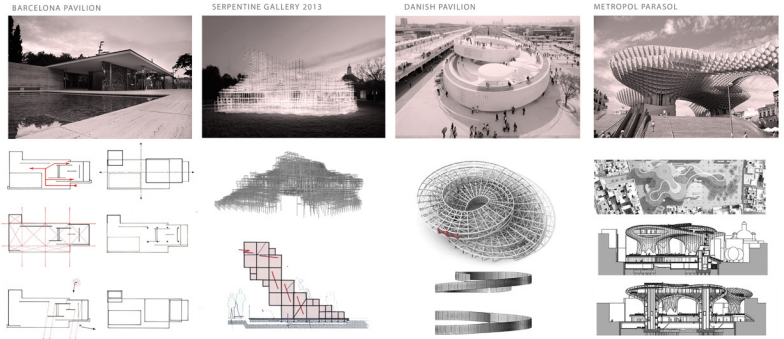


"If architects designed a building like a body, it would have a system of bones and muscles and tendons and a brain that knows how to respond."
-Guy Nordensson

CASE STUDY

In architecture, "a pavilion (from French pavillon, from Latin papilio) has several meanings. In architectural terminology it refers to a subsidiary building that is either positioned separately or as an attachment to a main building. Often its function makes it an object of pleasure."

Each Pavilion provides a lesson in the extreme possibilities of built form and demonstrates that many of the biggest ideas in architecture and gives a glimpse of the near future of architecture. One way of conceptualizing the pavilion across time and space is a structure of transient and often modest presence in the otherwise rather weighty ideas.



NATURES FUNCTION

ORGANISM	TERRESTRIAL MOUND	TREE	CELL MEMBRANE	DESERT MOUND	PINE
EXAMPLE					
FUNCTION	REGULATES THE GAS EXCHANGE	WATER AND NUTRIENTS	REGULATES IONS AND WATER	CHANNELS WATER	SCALES OPEN AND CLOSE
IMAGE					

INSPIRED BY NATURE

"Biomimetic" nature is the source of inspiration to create "artificial systems that copy function from natural ones (Vincent). This theory has always inspired different fields of knowledge from the arts, philosophy, technology, physics, politics, medicine and of course architecture, but when it comes to the structural properties of architecture this system was not explored until the 20th century when it led to the inspiration of lightweight structures (Garcia). In Figure 1, the general use of construction methods was applied without the intervention and analysis of the nature.

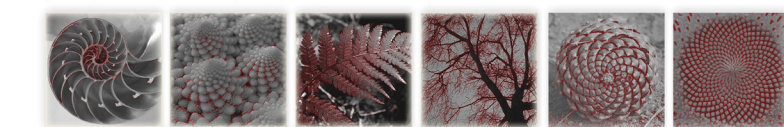
The formation of studies done by Ernst Haeckel in his book Art Forms of Nature looks at microorganisms through an artistic and aesthetic analysis. During the same period, the book On Growth and Form was published, by biologist D'Arcy Thompson. He explained that "animal forms as funiculars of force" both brought out the possibilities of new forms and structural systems that were directly influenced by nature. Leading to "optimal morphology extreme lightening, functional integration, and efficiency" in structure (Garcia 4). In Figure 2) radiolarians studied by Haeckel influence the structural systems of the Planetarium in Jena.

UNDERSTANDING FRACTALS

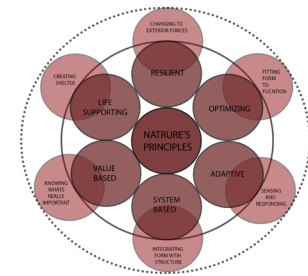
The importance of a fractal system is crucial when applying to the general outcome of this design. The fractal system is defined in the 1970s stating that it is a system that concludes in the abstract configurations of self-similar patterns and a recursive growth (Maderholt 4). Looking at this system through a mathematical point of view can allow for a system to decrease and increase in scale. The figure below shows a recursive algorithm applied to a simple cube formation that represents the fractal system in a three-dimensional form. At each stage from 1-5, the model increased the amount of surface but kept the initial volume. This system was represented as a decreasing pattern with the possibilities of having an infinite amount of cubes but not increasing the volume content of the original cube.

FRACTALS FOUND IN NATURE

Fractals are in many scenarios not dependent on geometric patterns, they also refer to the process by which time and evolution have a direct impact when referring to the natural occurrence of fractals in nature. For many centuries, nature's forms in many cases present fractal geometry in the structural sense, such as trees, shells, vegetables, etc. These systems can be seen in the use of light weighted structures such as arches, tents, grid shell, bridges to name a few. Fractals can be conceived by the method in today digital world by the use of 3d modeling, and through the process of a generative approach based on mathematical composition (Huylenbroeck)

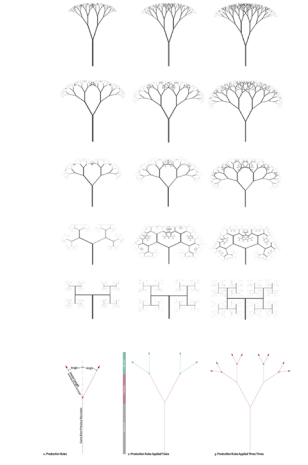


FRACTAL DESIGN | DECODING NATURE

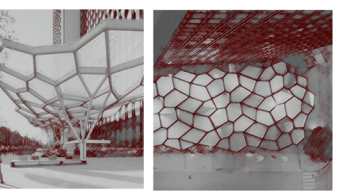


FRACTAL BRANCHING OF TREES

Trees with their branches are one of the finest examples of nature's fractals that are self-similar in pattern and highly irregular. These are different explanations about the tree's fractal-like branching appearance from different angles of disciplines such as biological, structural and mechanical. However, the basic explanation is functional needs. The total length of all branches and stems, are uniform in energy utilization the changing of sun path from morning to evening. But, at the same time, for basic biological needs, all leaves spread over large surface area.

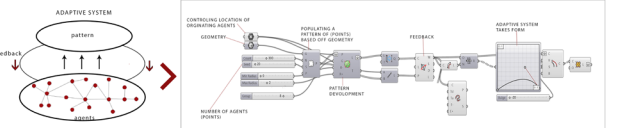


With these production rules, after each generation the number of Lines doubles. By varying the angle of branching and the proportion of reduction for each generation, though, the formal expression of the production rules can be quite different. I coded these production rules in an Anemone loop in Grasshopper, and after a fixed number of generations (much more than 7 or 8 generations will be overkill!) it draws pipes along each line with the radius of the Pipe based on the overall length of the line. Script image to follow a bit later

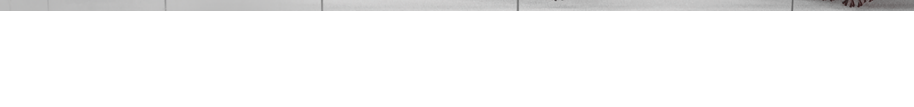
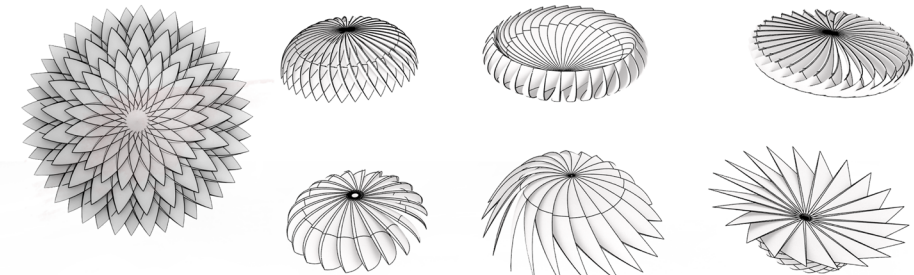
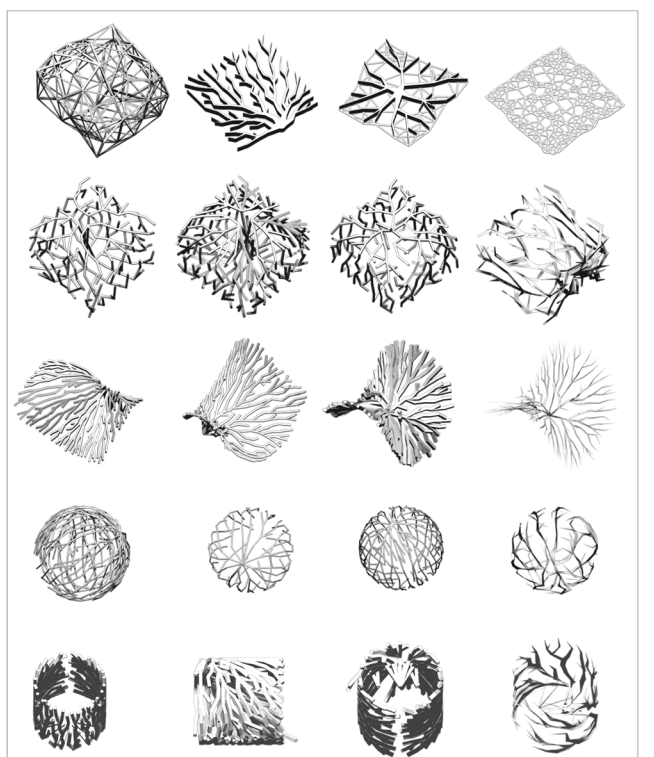
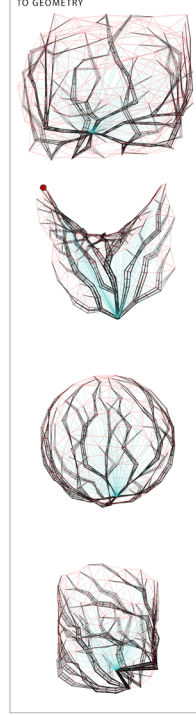


The design exploration dealt with understanding the parametric portion of a fractal system when referred to branching as well as vein patterns. Through this process, I adapted the fractal branching on basic geometrical shapes, the methodology was through the use of 5 of 3d minimal spanning tree generated by inner points, boundary points, random boundary points, inner and boundary points, inner and random boundary points, geometry attractors, boundary circles, gradient, going through this process revealed some constraints of the networking of curves, but as well brought about the adaptation portion of this project.

These agents interact and connect with each other in unpredictable and unplanned ways. But from this mass of interactions regularities emerge and start to form a pattern which feeds back on the system and informs the interactions of the agents. For example in an ecosystem if a virus starts to deplete one species this results in a greater or lesser food supply for others in the system which affects their behaviour and their numbers. A period of flux occurs in all the populations in the system until a new balance is established.



SYSTEM APPLIED TO GEOMETRY



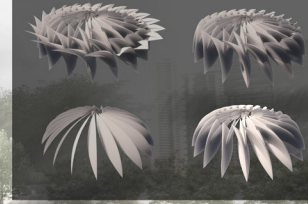
PIEDMONT PAVILION

A Pavilion of Adaptation

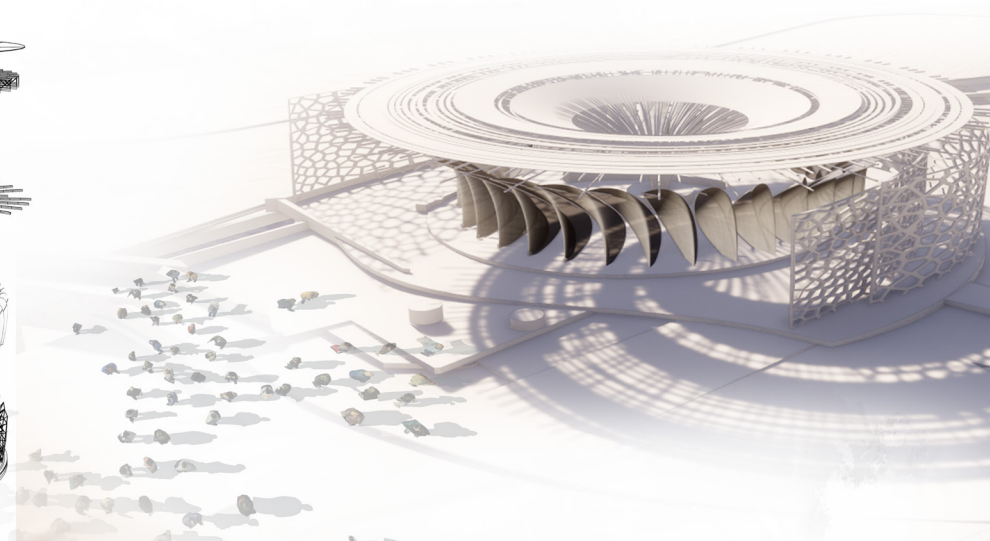
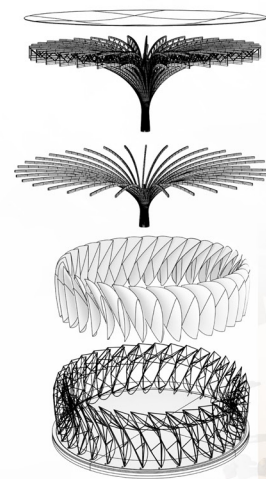
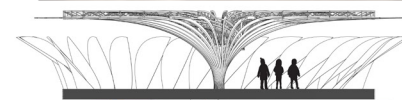
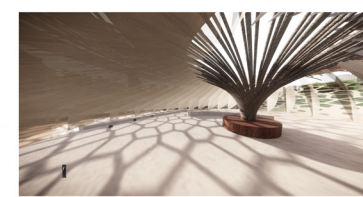
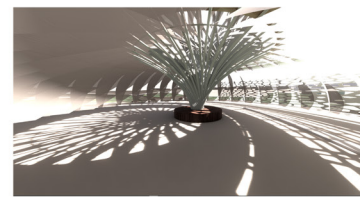
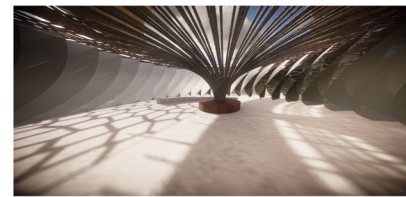
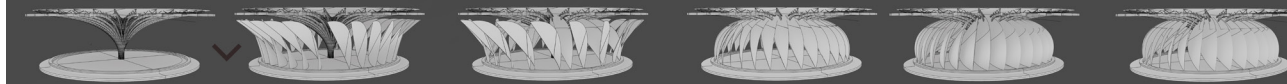


DESIGN SYNTHESIS

The concept of a piece of architecture taking on adaptive qualities is based on the ability that a system can effectively respond to the environment and the evolving programs. Architects strive to create designs that respond to external change, creating a challenge with kinetic and the immediate aspects of a building, which can be identified as the system of walls, ceiling, and columns. This system however, creates the foundation of a successful built environment but also hinders the adaptive and flexible qualities. These systems are implemented permanently and confined to the site and program that has been defined to them. Keeping this challenge in mind, one cannot help to see nature and be inspired by the adaptive and the systematic qualities that nature constantly is using, from the fractal branching of a tree to the efficient way of filling space in a honeycomb. We can start seeing a trend in nature and the adaptive qualities it tends to.



ADAPTIVE CONTROL



Block,P.,Ochsendorf,J.,2008.Lower-boundanalysisofmasonry vaults.In:Proceedingsofthe6thInternationalConferenceon StructuralAnalysisofHistoricalConstruction.Bath,UK.

Department of Architecture and Design (DAD), Politecnico di Torino, Viale Pier Andrea Mattioli – 39, Turin 10125, Italy

James,K.R.,Haritos,N.,Ades,P.K.,2006.Mechanicalstabilityof treesunderdynamicloads. Am.J.Bot.93(10),1522–1530.

Jodidio, Philip. The New Pavilions. Thames & Hudson, 2016.

Kang,H.S.,Dennis,D.,Meneveau,C.,2011.Flowoverfractals: dragforcesandnearwakes.Fractals19(04),387–399.

Otto F., Growing and dividing pneus, in IL 19: Growing and dividing pneus. Institute for Lightweight Structures, University of Stuttgart, 1979. 22-97

Perez-Garcia, Agustin & Gómez-Martínez, Fernando. (2009). Natural structures: Strategies for geometric and morphological optimization. Universitat Politècnica de València International Association for Shell and Spatial Structures (IASS) Symposium. .

Pearce P., Structure in Nature is a strategy for design. Cambridge [etc.]: MIT Press, 1990

See Nigel Whitely’s biography Reyner Banham: Historian of the Immediate Future, Cambridge, U.K., Cambridge University Press, 2002.

VincentJ.,StealingideasfromNature,inRSAJournal,August/September1997,36-43

TABLE 1: Solga, A., Cerman, Z., Striffler, B. F., Spaeth, M., and Barthlott, W., 2007, “The Dream of Staying Clean: Lotus and Biomimetic Surfaces,” Bioinspiration

Images

Kinetic Diagram-<https://www.designboom.com/project/adaptive-skins/>

Figure 1-<https://www.designboom.com/project/adaptive-skins/>

Fractal Geometry-<http://www.fractal.org/Bewustzijns-Besturings-Model/Fractals-Useful-Beauty.htm>

Branching Fractals-<https://www.wired.com/2010/09/fractal-patterns-in-nature/>
Water Cube

PNUE Home-<https://www.curbed.com/2018/2/9/16997272/pneuhaus-compound-camera-inflat-able-dome>

WestendGate-<https://www.archdaily.com/175519/westendgate-just-burgeff-architekten-a3lab>

ICD/ITKE Research Pavilion 2011-<https://visuall.net/2012/05/22/icditke-research-pavilion-2011/>

Serpentine pavilion 2016-<http://www.serpentinegalleries.org/explore/pavilion>

Aegis Hyposurface-<http://blog.kineticarchitecture.net/2008/12/aegis-hyposurface/>

Barcelona PAvilion-<http://portfolios.mica.edu/gallery/32450807/Precedent-Study-Barcelona-Pavilion>

Serpentine Gallery 2013-<http://www.prweb.com/releases/2013/12/prweb11438067.htm>

Danish Pavilion-<https://www.spans-associates.com/danish-pavilion-shanghai-expo-arup-agu/>

Metropol Parasol-<https://inhabitat.com/metropol-parasol-the-worlds-largest-wooden-structure-opens-in-seville/metropolparasol1/>

Piedmont Park Expantion Concept-<https://atlanta.curbed.com/2018/1/2/16835620/piedmont-park-expansion-monroe-drive>